Impacts of Sowing Date, Cultivar, Irrigation Regimes and Location on Bread Wheat Production in Egypt under Climate Change Conditions

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Abstract: Impacts of climate change will have significant reflections on field practices of wheat growers. The present work is mainly directed to discuss sensitivity of climate change upon the wheat production in Egypt. Field experiments were conducted at three different agroclimatic locations (Sakha, Sids and Shandaweel) at winter season of 2009/2010 to study the effects of two sowing dates and three irrigation levels (60, 80 and 100% of the full water requirements) on grain yield and its attributes of four bread wheat, *Triticum aestivum,* cultivars (Gemmeiza 9, Giza 168, Sakha 93 and Misr 1). Experimental conditions and results obtained from those locations were used as a database for calibration of CERES-Wheat model under DSSAT4.5 package to study the sensitivity of climate change on wheat growth and yield. Two climate change scenarios have been employed with changes in temperature. The first scenario supposed that increasing in temperature of 1.5°C would happen, and the second scenario supposed that increasing of 3.5°C would happen. The results showed that by comparing results obtained from CERES-Wheat model and actual observations in the field enabled us to reach very good calibration and validation of the model for predicting phonological stages as well as grain yield at different locations using different treatments. 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 +1.5°C scenario, reduction in grain yield, as predicted by the model, will be in average among cultivars of 12% at Sakha location, 9% at Sids location and 11% at Shandaweel location. Scenario of +3.5°C will reduce grain yield within an average of 27% at both Sakha , Sids locations, and 31% at Shandaweel location. We can conclude that reduction in wheat grain yield at the three locations has high probability in the future with accelerating growing cycle, especially at +3.5°C, which needs to define earlier sowing suitable dates and adaptive agronomical practices.

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1. Introduction

The frequency and magnitude of extreme weather events are expected to increase under climate change (Solomon *et al.* 2007). In a warmer future climate, most global climate models (GCM) simulate increased summer dryness and winter wetness in most parts of the northern middle and high latitudes. 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 & 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. Using UKCIP02-based climate projections for the UK (Hulme *et al.* 2002), it has been demonstrated that by the end of the century, not only will the frequency of heat waves increase substantially (by an order of magnitude), but also their length and severity with higher peak temperatures during a heat wave (Semenov 2007). Several crop simulation models have been released and developed in the last two decades. Few of these models are truly predicting growth, development, and yield of a given crop. Simulation models are often used to verify the potentiality of crop management, allowing multi-year and multi-location runs with minimum time spending (Rinaldi and Ubaldo, 2007). Plants at different growth stages can be simulated and the outputs can be evaluated according to different categories using crop simulation models. The Decision Support System for Agrotechnology Transfer (DSSAT) is a software application program that comprises crop simulation models for over 28 crops, as of Version 4.5 (DSSAT.net, 2011). The choice of such model was because of its ability to simulate growth, development, and yield of several crops. CERES-Wheat model (Godwin *et al.,* 1981; Ritchie and Otter, 1985) is a simulation model for wheat in the DSSAT package that describes daily phenological development and growth in response to environmental factors (soils, weather and management). The primary variable influencing phasic development rate is temperature (Iglesias, 2006). Temperature also is the primary factor driving wheat development (Wilhelm and McMaster, 1995), and consequently influence yield (McMaster, 1997). Numbers of tillers are usually decreased when wheat plants were exposed to high temperature (Friend 1965). In addition, temperature is the major variable controlling spikelet initiation and development rates (McMaster, 1997). Furthermore, high temperature during anthesis causes pollen sterility (Saini and Aspinall, 1982) and reduces number of kernels per head, if it prevailed during early spike development (Kolderup, 1979). At higher temperature, the duration of grain filling period was reduced (Sofield *et al.,* 1977) as well as growth rates with a net effect of lower final kernel weight (Bagga and Rawson 1977; McMaster, 1997). Therefore, it is expected that climate change will have implications for possible fluctuation on wheat yield (Wrigley, 2006). Climate change could implement severe damage to agricultural productivity if no adaptation measures are taken (El-Shaer *et al.* 1997). Most of the previous research on the impact of climate change on agricultural sector in Egypt used two scenarios, i.e. 1.5°C rise in temperature (MAGICC/SCENGEN results) 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 by up to 30% and increase in water needs by to 3% (Eid *et al.,* 1992; Eid *et al.,* 1993 and Eid *et al.,* 1994) in the year of 2050. Thus, the effects of climate change on wheat production will control the future of food security in Egypt, especially under the existence of large gap between wheat production and consumption. For that reason, more research for adaptation strategies should be explored to reduce the vulnerability of the system to climate change. The aim of this research is to use DSSAT model to simulate wheat yield under the climate change scenarios and to use the model to test the effect of different sowing dates and irrigation levels as an adaptation option on relieving the harm effect of climate change on wheat yield and water use efficiency.

2. Materials and Methods

1. Field experiments

Field experiments were conducted at three different agroclimatic locations: Sakha (31° 7’ N; 30° 56’ E), Sids (29° 4’ N; 31° 6’ E), and Shandaweel (31° 39’ N; 26° 37’ E). The season was winter of 2009/2010 to study the effects of two sowing dates (the recommended and 15 days later) and three irrigation levels (60, 80 and 100% of the full water requirements) on grain yield and its attributes of four bread wheat cultivars (Gemmeiza 9, Giza 168, Sakha 93 and Misr 1). Climatic data during the winter season (2009/2010) for the three locations were obtained from Central Laboratory for Agriculture Climate (CLAC), Egypt (Table1).

2. Crop Model Validation

Experimental conditions and results obtained from those locations (Sakha, Sids and Shandaweel) were used as a database for calibration and validation of CERES-Wheat model through DSSAT 4.5 software to simulate and predict wheat yield. The comparison between actual data 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.

3. 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 1.5°C and 3.5°C to maximum and minimum temperatures of the winter season 2009/2010 starting from the best sowing date indicated at conducted field experiments for different locations and finishing by the end of growing cycle.

3. Results and discussion

1. Calibration and validation of CERES-Wheat model

Results obtained from experimental field studies were as indicators to test performance of CERES-Wheat model at three agroclimatic locations using different treatments of changing sowing dates from normal time to 15 days later and different irrigation levels (60, 80 and 100%) for four bread wheat cultivars (Gemmeiza 9, Giza 168, Sakha 93 and Misr 1). Hereafter we can observe harmony between observed values of field measurements and predicted values obtained by the model of two sowing dates and different irrigation levels at Sakha, Sids and Shandaweel locations. Regarding changing sowing dates and the effect of different irrigation levels, data showed that using first sowing date and 100 % irrigation level increased wheat yield as compared to late sowing date and other irrigation levels. The lowest wheat yield was obtained by second sowing date at 60 % irrigation level treatment. 100 % irrigation level gave the highest value for four cultivars yield compared to the other irrigation levels for the observed and predicted data in the first and second sowing date. Gemmeiza 9 cultivar gave the longest observed and predicted number of days for anthesis date and physiological maturity date at different irrigation levels and sowing dates. Sakha 93 cultivar gave the shortest observed and predicted number of days for anthesis date and Misr 1 cultivar gave the shortest observed and predicted number of days for physiological maturity date at different irrigation levels and sowing dates. Giza168 cultivar gave the highest predicted value for grain yield at different irrigation levels and sowing dates, but Sakha 93 and Misr 1 gave the lowest predicted value for grain yield at Sakha location (Table2 and Table3). At Sids location, Misr 1 cultivar gave the highest predicted value for grain yield at different irrigation levels and first sowing date but in the second sowing date and two irrigation levels (100 and 80%) Misr 1 cultivar gave the highest predicted value for grain yield and at 60 % irrigation level; Giza168 cultivar gave the highest predicted value for grain yield. Gemmeiza 9 cultivar gave the lowest predicted value for grain yield at different irrigation levels and sowing dates (Table4 and Table5). For Shandaweel location, Misr 1 cultivar gave the highest predicted value for grain yield and Gemmeiza 9 cultivar gave the lowest predicted value for grain yield at different irrigation levels and sowing dates (Table6 and Table7). Simulation ability of the model was similar to what obtained by Hassanein 2007, Ouda *et al* 2005 and Rayan *et al.*, 1999.

The d-Stat index of agreement, as absolute values, between observed and predicted values for Sakha, Sids and Shandaweel locations was from 59 to 71 % for the anthesis date and from 43 to 93 % for physiological maturity date. For grain yield the d-Stat index of agreement between expected observed and predicted values was from 53 to 87 %.

2. **Evaluating climate change impacts on wheat using CERES-Wheat model**

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 1.5°C and 3.5°C to maximum and minimum temperatures of the winter season 2009/10 starting from the recommended sowing date for different locations and finishing by the end of growing cycle. Four bread wheat cultivars have been used in these studies which were Gemmeiza 9, Giza 168, Sakha 93, and Misr 1. These cultivars have been calibrated using previous field experiments in the three different agroclimatic locations.

2.1 Anthesis date

Adding 1.5°C to minimum and maximum temperature will cause a reduction in growing cycle length of wheat for all cultivars under study (Figure1, Figure2 and Figure3). Reduction will be about 15 days required period for anthesis for all cultivars. Gemmeiza 9 and Giza 168 cultivars will have longer period to anthesis than Sakha 93 and Misr 1 cultivars with about 5 days. Length of growing cycle will be more reduced at Shandaweel location followed by Sids location and Sakha location, respectively. Greater impacts will be observed by adding 3.5°C to minimum and maximum temperature creating more reduction in period required to anthesis with about 18 to 20 days. This reduction will be more for Sakha 93 and Misr 1 cultivars than for Gemmeiza 9 and Giza 168 cultivars which have shorter growing cycle in current conditions. Plants under Shandaweel weather conditions will need shorter period to arrive to anthesis than plants in Sids and Sakha, respectively.

Comparing the reduction in days to anthesis at both future climate scenarios showed reduction by adding 3.5°C doubled than reduction caused by adding 1.5°C at all locations (Figure10, Figure11 and Figure12). At Sakha location, reduction at +3.5°C was similar for all cultivars under study, while at Sids location reduction was more for Misr 1 cultivar with about 5 days. At Sahndaweel location, reduction in days to flowering was more for Sakha 93 cultivar with about 5 days more than other cultivars under the same weather conditions.

2.2 Physiological maturity date

Adding 1.5°C to minimum and maximum temperature will cause a reduction in growing cycle length of wheat for all cultivars under study (Figure4, Figure5 and Figure6). Reduction will be about 10 days required period for physiological maturity for all cultivars. Gemmeiza 9 and Giza 168 cultivars will have longer period to physiological maturity than Sakha 93 and Misr 1 cultivars with about 5 days. Length of growing cycle will be reduced more at Shandaweel location followed by Sids location and Sakha location, respectively. Greater impacts will be observed by adding 3.5°C to minimum and maximum temperature creating more reduction in period required to physiological maturity with about 18 to 20 days. This reduction will be more for Sakha 93 and Misr 1 cultivars than for Gemmeiza 9 and Giza 168 cultivars which have shorter growing cycle in current conditions. Plants under Shandaweel weather conditions will need shorter period to arrive to physiological maturity than plants in Sids and Sakha locations, respectively.

Comparing the reduction in days to physiological maturity at both future climate scenarios showed reduction by adding 3.5°C doubled than reduction caused by adding 1.5°C at all locations (Figure13, Figure14 and Figure15). At Sakha location, reduction at +3.5°C was similar for all cultivars under study, while at Sids location reduction was more for Gemmeiza 9 and Giza 168 than other cultivars with about 5 days. At Sahndaweel location, reduction in days to physiological maturity was more for Gemmeiza 9, Giza 168 and Misr 1 cultivars than Sakha 93 cultivar with about 3 days.

2.3 Grain yield

Comparing effect of adding 1.5°C and 3.5°C to minimum and maximum temperature with the current weather conditions showed more reduction in grain yield of wheat for all cultivars under study at +3.5°C more than +1.5°C and current conditions (Figure7, Figure8 and Figure9). Reduction will be about 400 kg/ha for each cultivars. Giza 168 cultivar will have higher yield at Sakha location while Misr 1 cultivar will have higher yield at both Sids and Shandaweel locations. Comparing performance of plants at different locations showed that grain yield at Sids location will arrive to 7500 kg/ha while it will be reduced to about 7000 kg/ha at Shandaweel location and about 5500 kg/ha at Sakha location. Greater reduction in grain yield observed by adding +3.5°C to minimum and maximum temperature which caused by reduction in period required to flowering and maturity. This reduction will be more for Gemmeiza 9 cultivar than for Sakha 93, Giza 168 and Misr 1 cultivars at all location.

Comparing the reduction in grain yield at both future climate scenarios showed reduction by adding 3.5°C doubled or more than reduction caused by adding 1.5°C at all locations (Figure16, Figure17 and Figure18). At both Sakha and Sids locations, reduction at +3.5°C was more for Gemmeiza 9 (900 kg/ha and 3000 kg/ha, respectively), while at Shandaweel location reduction was more for Giza 168 cultivar with about 3000 kg/ha. At Shandaweel location, reduction in grain yield will be more dramatical for all cultivars under study. Sakha 93 cultivar showed resistance in front of future rising in climate temperature at both Sids and Shandaweel locations. More resistant cultivars and changing planting dates and water regimes could be useful tools to avoid or reduce negative effects of future rising in climate temperature on wheat plants.

Table 1: Maximum and minimum temperature of the studied locations.

Month	Maximum Temperature (°C)			Minimum Temperature (°C)		
	Sakha	Sids	Shandaweel	Sakha	Sids	Shandaweel
Nov. -2009	24.9	24.7	31.6	14.7	14.7	14.1
Dec. -2009	24.6	24.4	31.0	14.8	14.7	14.0
Jan. -2010	20.9	25.0	25.9	13.7	12.0	12.3
Feb. -2010	20.5	24.2	25.6	13.3	11.9	12.1
Mar. -2010	21.5	25.8	27.3	13.8	12.6	12.9
Apr. -2010	22.1	26.6	28.3	13.8	12.7	13.2
May -2010	23.0	27.7	29.6	14.0	13.1	13.6
Average	22.5	25.5	28.5	14.0	13.1	13.2

Table 2: Simulated and observed values of wheat for the first sowing date at Sakha location.

Irrigation	Cultivar	Anthesis date			Physiological maturity			Grain yield (kg/ha)		
		Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*
100	Gemmeiza 9	139	131	0.56	178	146	0.55	4300	5005	0.54
	Giza 168	129	131	0.64	175	146	0.60	4900	5584	0.60
	Sakha 93	128	125	0.76	175	141	0.60	4200	4857	0.65
	Misr 1	131	125	0.62	173	141	0.63	4700	4857	0.77
80	Gemmeiza 9	138	131	0.53	181	146	0.52	4200	4722	0.54
	Giza 168	129	131	0.66	177	146	0.56	4300	5156	0.60
	Sakha 93	128	125	0.67	177	141	0.57	4800	4793	0.65
	Misr 1	131	125	0.61	175	141	0.61	4100	4793	0.77
60	Gemmeiza 9	139	131	0.54	182	146	0.52	4000	3965	0.54
	Giza 168	128	131	0.67	174	146	0.57	3900	4315	0.60
	Sakha 93	127	125	0.68	176	141	0.60	3600	4092	0.65
	Misr 1	131	125	0.63	174	141	0.62	4000	4092	0.77

*The Index of Agreement (d) as described by Willmott *et al.* (1985).

Table 3: Simulated and observed values of wheat for the second sowing date at Sakha location.

Irrigation	Cultivar	Anthesis date			Physiological maturity			Grain yield (kg/ha)		
		Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*
100	Gemmeiza 9	118	125	0.56	159	139	0.55	4200	4870	0.54
	Giza 168	113	125	0.64	155	139	0.60	4100	5386	0.60
	Sakha 93	110	120	0.76	155	134	0.60	3400	4679	0.65
	Misr 1	114	120	0.62	153	134	0.63	4500	4679	0.77
80	Gemmeiza 9	120	125	0.53	161	139	0.52	4000	4429	0.54
	Giza 168	112	125	0.66	158	139	0.56	3600	4807	0.60
	Sakha 93	110	120	0.67	157	134	0.57	3200	4333	0.65
	Misr 1	115	120	0.61	154	134	0.61	4300	4333	0.77
60	Gemmeiza 9	120	125	0.54	161	139	0.52	3900	3535	0.54
	Giza 168	112	125	0.67	157	139	0.57	3600	3763	0.60
	Sakha 93	110	120	0.68	155	134	0.60	3100	3604	0.65
	Misr 1	113	120	0.63	153	134	0.62	4000	3604	0.77

*The Index of Agreement (d) as described by Willmott *et al.* (1985).

Table 4: Simulated and observed values of wheat for the first sowing date at Sids location.

Irrigation	Cultivar	Anthesis date			Physiological maturity			Grain yield (kg/ha)		
		Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*
100	Gemmeiza 9	118	113	0.68	153	167	0.78	8400	6306	0.62
	Giza 168	120	113	0.69	160	167	0.87	7400	7223	0.84
	Sakha 93	120	125	0.68	156	175	0.67	6000	6611	0.81
	Misr 1	118	107	0.69	151	159	0.78	7800	7560	0.76
80	Gemmeiza 9	120	113	0.68	157	167	0.84	6800	5499	0.65
	Giza 168	118	113	0.68	154	167	0.79	6500	6245	0.80
	Sakha 93	120	125	0.69	160	175	0.88	5600	5576	0.70
	Misr 1	120	107	0.68	156	159	0.81	6200	6611	0.77
60	Gemmeiza 9	121	113	0.69	161	167	0.88	6000	4013	0.76
	Giza 168	120	113	0.68	156	167	0.83	5600	4794	0.86
	Sakha 93	118	125	0.68	153	175	0.79	5400	4409	0.83
	Misr 1	119	107	0.69	161	159	0.87	6000	5096	0.82

*The Index of Agreement (d) as described by Willmott *et al.* (1985).

Table 5: Simulated and observed values of wheat for the second sowing date at Sids location.

Irrigation	Cultivar	Anthesis date			Physiological maturity			Grain yield (kg/ha)		
		Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*
100	Gemmeiza 9	66	99	0.68	110	146	0.78	3700	5092	0.62
	Giza 168	68	99	0.69	118	146	0.87	4000	5772	0.84
	Sakha 93	66	107	0.68	113	153	0.67	3500	5388	0.81
	Misr 1	65	96	0.69	111	144	0.78	3800	5896	0.76
80	Gemmeiza 9	66	99	0.68	115	146	0.84	3400	4667	0.65
	Giza 168	66	99	0.68	111	146	0.79	3600	5159	0.80
	Sakha 93	68	107	0.69	119	153	0.88	3200	4904	0.70
	Misr 1	67	96	0.68	113	144	0.81	3700	5281	0.77
60	Gemmeiza 9	70	99	0.69	119	146	0.88	2700	2412	0.76
	Giza 168	67	99	0.68	115	146	0.83	3300	2756	0.86
	Sakha 93	66	107	0.68	111	153	0.79	3200	2734	0.83
	Misr 1	69	96	0.69	118	144	0.87	3300	2666	0.82

*The Index of Agreement (d) as described by Willmott *et al.* (1985).

Table 6: Simulated and observed values of wheat for the first sowing date at Shandaweel location.

Irrigation	Cultivar	Anthesis date			Physiological maturity			Grain yield (kg/ha)		
		Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*
100	Gemmeiza 9	116	111	0.71	160	160	0.77	5500	5683	0.67
	Giza 168	115	107	0.87	156	157	0.87	5000	6056	0.47
	Sakha 93	122	122	0.73	161	168	0.73	5700	6046	0.68
	Misr 1	121	107	0.64	164	157	0.64	7100	7105	0.69
80	Gemmeiza 9	118	111	0.78	158	160	0.78	5400	5313	0.89
	Giza 168	114	107	0.89	155	157	0.89	4800	5581	0.55
	Sakha 93	122	122	0.74	162	168	0.74	5400	5536	0.85
	Misr 1	122	107	0.66	163	157	0.66	6200	6499	0.78
60	Gemmeiza 9	117	111	0.77	157	160	0.77	5100	3315	0.45
	Giza 168	116	107	0.80	158	157	0.80	4600	3625	0.36
	Sakha 93	123	122	0.73	161	168	0.73	5100	3528	0.42
	Misr 1	122	107	0.64	165	157	0.64	5500	4024	0.40

*The Index of Agreement (d) as described by Willmott *et al.* (1985).

Table 7: Simulated and observed values of wheat for the second sowing date at Shandaweel location.

Irrigation	Cultivar	Anthesis date			Physiological maturity			Grain yield (kg/ha)		
		Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*
100	Gemmeiza 9	86	102	0.71	142	148	0.77	5200	4906	0.67
	Giza 168	85	100	0.87	140	145	0.87	4200	5035	0.47
	Sakha 93	92	111	0.73	144	156	0.73	4600	5771	0.68
	Misr 1	91	100	0.64	148	145	0.64	5400	5853	0.69
80	Gemmeiza 9	87	102	0.78	143	148	0.78	4200	4317	0.89
	Giza 168	86	100	0.89	140	145	0.89	4200	4468	0.55
	Sakha 93	91	111	0.74	143	156	0.74	4500	5286	0.85
	Misr 1	90	100	0.66	147	145	0.66	5200	5320	0.78
60	Gemmeiza 9	88	102	0.77	144	148	0.77	3900	2731	0.45
	Giza 168	86	100	0.80	141	146	0.80	4100	2878	0.36
	Sakha 93	92	112	0.73	144	156	0.73	4200	3169	0.42
	Misr 1	91	100	0.64	148	146	0.64	5200	3263	0.40

*The Index of Agreement (d) as described by Willmott *et al.* (1985).

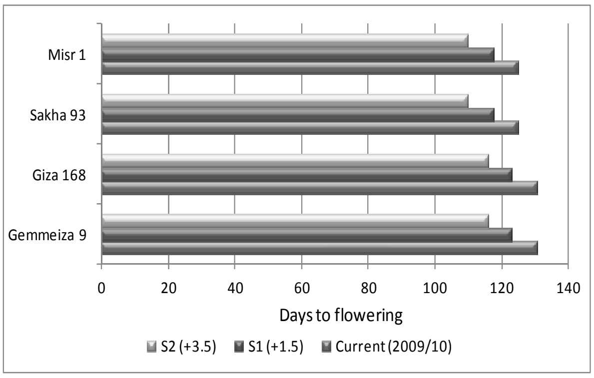

Figure 1: Changes in number of days to anthesis for wheat cultivars under current conditions (season 2009/10) and with addition of 1.5°C (S1) and 3.5°C (S2) at Sakha location.

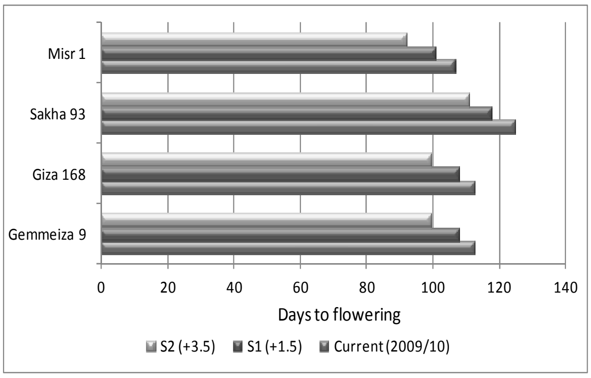

Figure 2: Changes in number of days to anthesis for wheat cultivars under current conditions (season 2009/10) and with addition of 1.5°C (S1) and 3.5°C (S2) at Sids location.

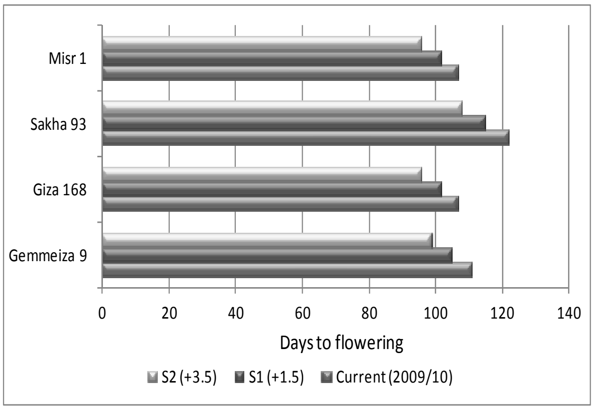

Figure 3: Changes in number of days to anthesis for wheat cultivars under current conditions (season 2009/10) and with addition of 1.5°C (S1) and 3.5°C (S2) at Shandaweel location.

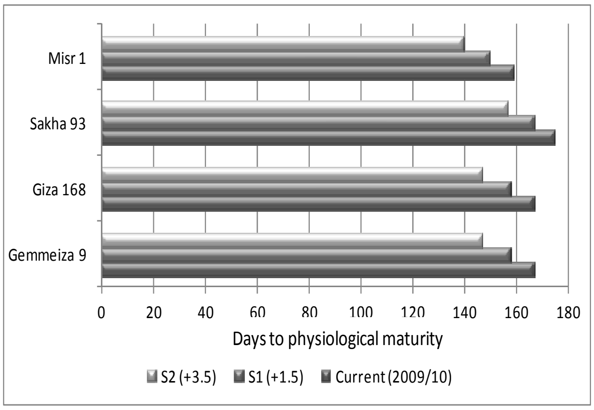

Figure 4: Changes in number of days to physiological maturity for wheat cultivars under current conditions (season 2009/10) and with addition of 1.5°C (S1) and 3.5°C (S2) at Sakha location.

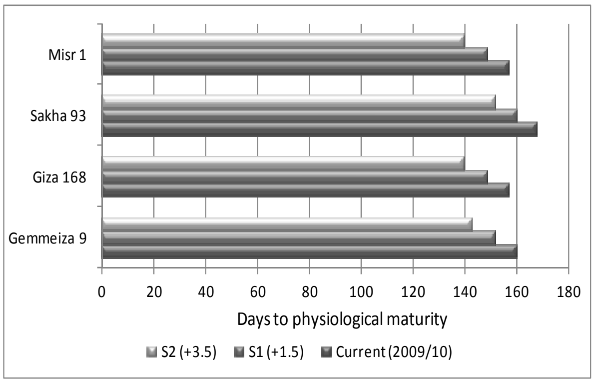

Figure 5: Changes in number of days to physiological maturity for wheat cultivars under current conditions (season 2009/10) and with addition of 1.5°C (S1) and 3.5°C (S2) at Sids location.

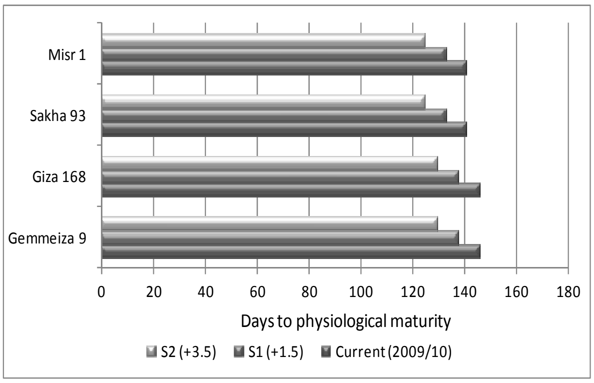

Figure 6: Changes in number of days to physiological maturity for wheat cultivars under current conditions (season 2009/10) and with addition of 1.5°C (S1) and 3.5°C (S2) at Shandaweel location.

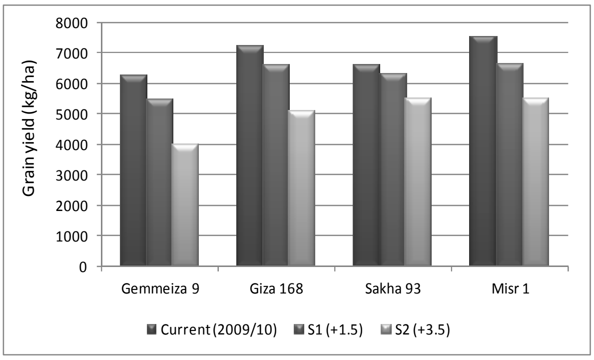

Figure 7: Changes in grain yield for wheat cultivars under current conditions (season 2009/10) and with addition of 1.5°C (S1) and 3.5°C (S2) at Sakha location.

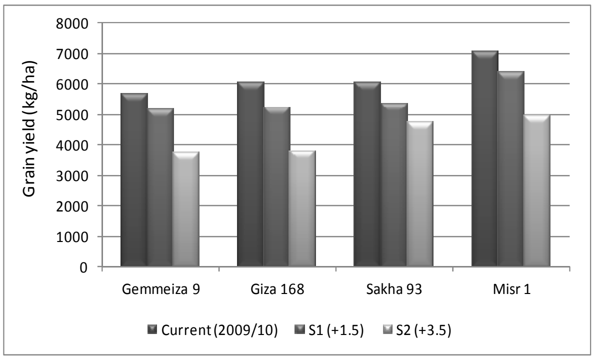

Figure 8: Changes in grain yield for wheat cultivars under current conditions (season 2009/10) and with addition of 1.5°C (S1) and 3.5°C (S2) at Sids location.

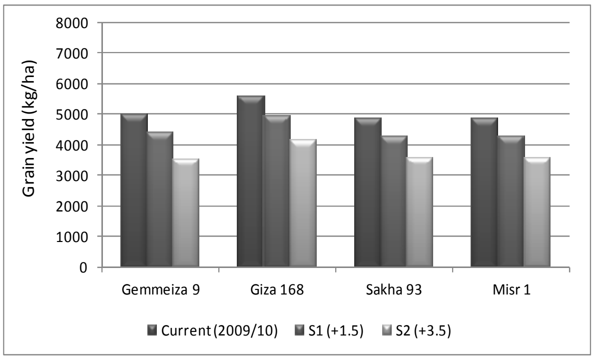

Figure 9: Changes in grain yield for wheat cultivars under current conditions (season 2009/10) and with addition of 1.5°C (S1) and 3.5°C (S2) at Shandaweel location.

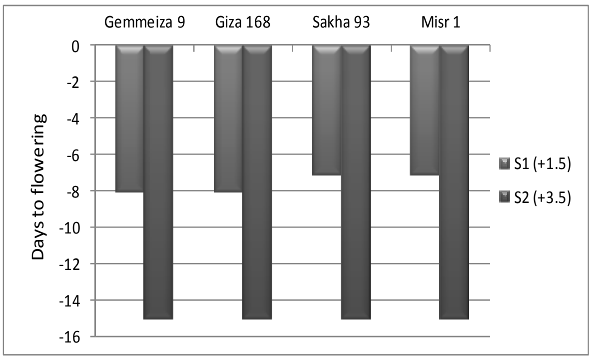

Figure 10: Effects of two climate change scenarios (S1 and S2) on number of days to anthesis (flowering) for wheat cultivars at Sakha location.

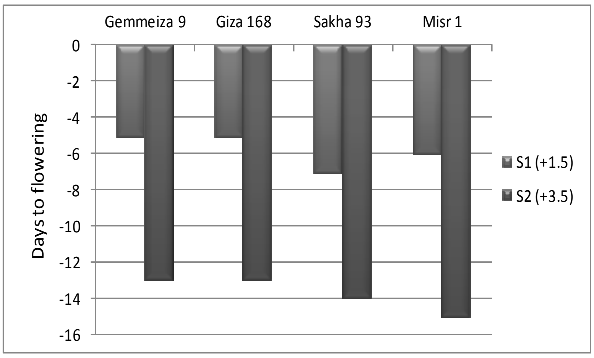

Figure 11: Effects of two climate change scenarios (S1 and S2) on number of days to anthesis (flowering) for wheat cultivars at Sids location.

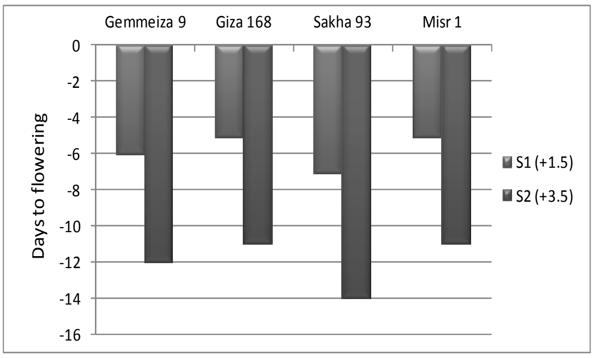

Figure 12: Effects of two climate change scenarios (S1 and S2) on number of days to anthesis (flowering) for wheat cultivars at Shandaweel location.

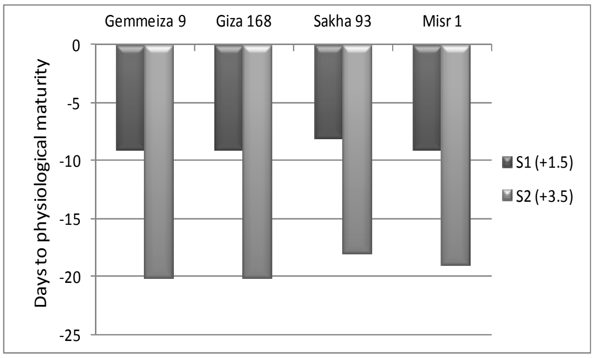

Figure 13: Effects of two climate change scenarios (S1 and S2) on number of days to physiological maturity for wheat cultivars at Sakha location.

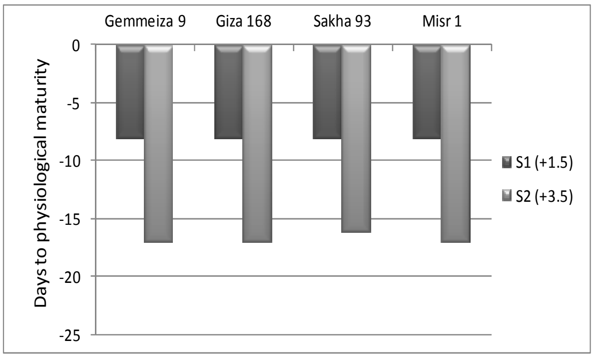

Figure 14: Effects of two climate change scenarios (S1 and S2) on number of days to physiological maturity for wheat cultivars at Sids location.

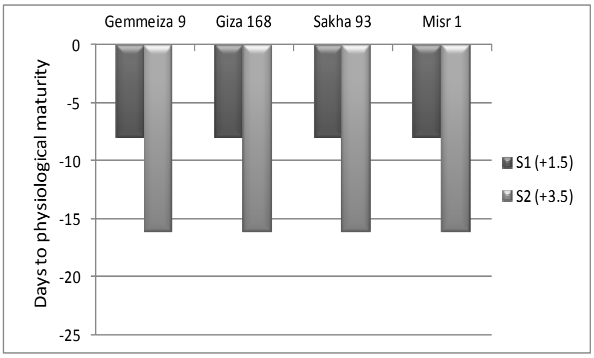

Figure15: Effects of two climate change scenarios (S1 and S2) on number of days to physiological maturity for wheat cultivars at Shandaweel location.

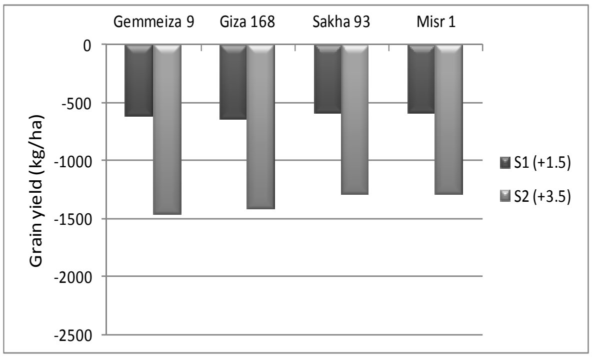

Figure16: Effects of two climate change scenarios (S1 and S2) on grain yield for wheat cultivars at Sakha location.

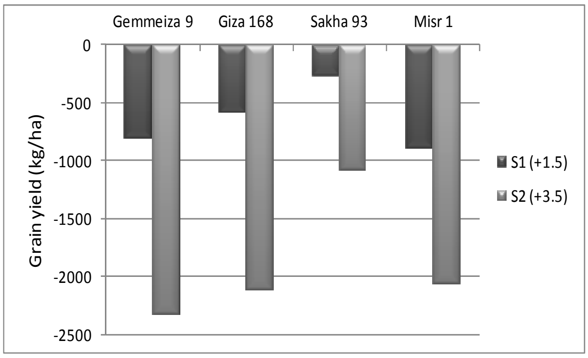

Figure17: Effects of two climate change scenarios (S1 and S2) on grain yield for wheat cultivars at Sids location.

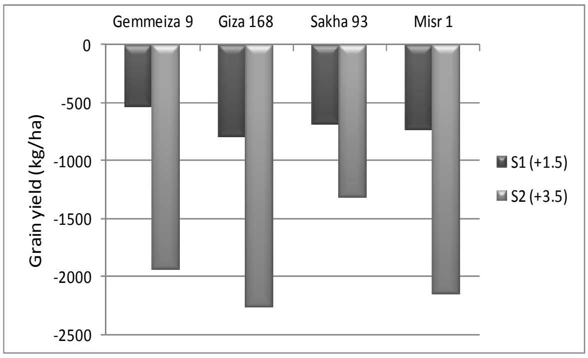

Figure18: Effects of two climate change scenarios (S1 and S2) on grain yield for wheat cultivars at Shandaweel location.

4. Conclusion

Simulation of wheat growth and yield using CERES-Wheat model at three agro climatic locations of Egyptian territory showed acceptable calibration and validation. Percentage of error between observed and predicted values vary between 60% and 93% for the most of evaluated parameters. Future simulation using climate change scenarios showed that wheat plants will be impaired by changes in air temperature as a function in locations. Plants at Sakha location will be less influenced by the increase in air temperature by 1.5°C, followed by Sids and Shandaweel locations, respectively. By the increase air temperature with 3.5°C, plants will lose ability to grow at the normal rate which will lead to significant loss in yield. Plants at different stages will be affected by the increase in air temperature, starting from anthesis date, going through length of growing cycle, and ending by both of physiological maturity and harvested yield.

References

1. Bagga, A.K., and I.M. Rawson. 1977. Contracting responses of morphologically similar wheat varieties to temperature appropriate to warm temperature climates with hot summers: A study in controlled environment. Australian Journal of Agricultural Research 40:965-980.
2. Barnett, D. N.;S. J .Brown; J.M.Murphy; D.M.H.Sexton & M.J.Webb2006; Quantifying uncertainty in changes in extreme event frequency in response to doubled CO2 using a large ensemble of GCM simulations. Clim. Dyn. 26, 489–511.
3. DSSAT.net, 2011. About DSSAT: The Decision Support System for Agrotechnology Transfer. http\\www.dssat.net.
4. Eid, H. M.; N. A. Anton; and A. M. Tarrad 1994. Comparative study on Egyptian wheat varieties and their response to high temperatures. Annals of Agric. Sci. Moshtohor Vol. 32 (1) 143-154.
5. Eid, H. M.; N. G. Ainer; M. A. Rady and W. M. Risk 1993. Impact of Climate change on simulated wheat yield and water needs. 1st. Conf. Egypt. Hung. Env. Egypt,:309-312.
6. Eid, H. M.; N. G. Ainer; K. M. R. Yousef; M. A. M. Ibrahim and G. M. Gad El-Rab, 1992. Climate change crop modeling study on wheat. 5th Egypt. Botan.Conf. Siant Cather. Sianai, p: 113-130.

7. El-Shaer, M. H.; C. Rosenzweig; A. Iglesias, H. M. Eid and D. Hellil, 1997. Impact of climate change on possible scenarios for Egyptian agriculture in the future. Mitigation and Adaptation Strategies for Global Change.1: 233-250.
8. Friend, D.J.C. 1965. Ear length and spikelet number of wheat grown at different temperatures and light intensities. Canadian Journal of Botany 43:343-353.
9. Godwin, D.;J. Ritchie; U. Singh; and L.Hunt 1981. A user's guide to CERES Wheat-V2.10. International Fertilizer Development Center. Simulation Manual IFDC-SM-2. Muscle Shoals, AL.
10. Hassanein, M. K. and M. A. Medany. 2007. Adapting the CERES-Wheat Model to Simulate Wheat under Current and Future Climates in Egypt. International Conference on Climatic Changes and Their Impacts on Coastal Zones and River Deltas: Vulnerability, Mitigation, and Adaptation. April 23-25, 2007, Alexandria, Egypt, pp: 66-81.
11. Hulme, M; G.J. Jenkins; X. Lu; J.R. Turnpenny; T.D. Mitchell; R.G. Jones; J. Lowe; J.M. Murphy; D. Hassell; P. Boorman; R. McDonald and S. Hill; 2002: Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report, Tyndall Centre for Climate Change Research, school of Envirnmental Sciences, University of East Anglia, Norwich, UK, 120 pp.
12. Iglesias, A., 2006. Use of DSSAT models for climate change impact assessment: Calibration and validation of CERES-Wheat and CERES Maize in Spain. CGE Hands-on Training Workshop on V&A Assessment of the Asia and the Pacific Region Jakarta, 20-24 March 2006-03-21.
13. Kolderup, I. 1979. Application of different temperatures in three growth phases of wheat. II. Effects on ear size and seed setting. Acta Agriculturae Scandinavica 29:11-116.
14. McMaster, G.S. 1997. Phonology, development, and growth of wheat (*Triticum aestivum L.*) shoot apex: A review. Advances in Agron. 59:63-118.
15. Ouda S.A; S.M. El-Marsafawy; M.A. El-Kholy and M.S. Gaballah 2005. Simulating the effect of water stress and different sowing dates on wheat production in South Delta. Journal of Applied Sciences Research, 1(3):268-276.
16. Rayan A.A; S.M. El-Marsafawy and K.A. Mohamed 1999. Response of some wheat varieties to different sowing dates and irrigation regimes in Upper Egypt. 3rd Conference of On-Farm Irrigation and Agroclimatology. SWERI, ARC (Egypt).
17. Ritchie, J. and S. Otter1985. Description of and performance of CERES-Wheat: A user-oriented wheat yield model. In W.O. Willis (ed). ARS Wheat Yield Project. Department of Agriculture, Agricultural Research Service. ARS-38. Washington, DC. pp. 159-175.
18. Rinaldi, M. and Ubaldo, R., 2007. Simulation at regional level of irrigated wheat and tomato in a Mediterranean environment WIT Transactions on Ecology and the Environment, Vol 103.
19. Saini, H. S. and D. Aspinall. 1982. Sterility in wheat (*Triticum aestivum L.*) induced by water stress or high temperature: Possible mediation by abscisic acid. Aust. J. Plant Physio. 9:529-537.
20. Sofield, I.L.; T. Evans, and I.F. Wardlaw. 1977. The effect of temperature and light on grain filling in wheat. Royal Society of New Zealand Bulletin 12:909-915.
21. Solomon, S.; D. Qin; M. Manning; M. Marquis; K. Averyt; M.M.B. Tignor; Leroy Miller, H. & Z. Chen (eds) 2007 Climate Change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovermental Panel on Climate Change. New York, NY: Cambridge University Press.
22. Semenov, M. A. 2007 Development of high resolution UKCIP02-based climate change scenarios in the UK. Agric. Forest Meteorol. 144, 127–138.
23. Wilhelm, W. W. and G. S. McMaster. 1995. The importance of phyllochron in studying the development of grasses. Crop Sci. 53:1-3.
24. Willmott, C. J; S.G. ackleson; R.E. davis; J.J. feddema; K.M. klink; D.R. legates; J. o'connell and C.M.Rowe1985. Statistics for the evaluation and comparison of models. Journal of Geophysical Research, 90: 8995-9005.
25. Wrigley, C. 2006. Global warming and wheat quality. CFW 51:34-36.
26. Weisheimer, A. and T.N.Palmer2005. Changing frequency of occurrence of extreme seasonal-mean temperatures under global warming. Geophysical Research Letters, 32:L20721.

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