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Evaluation and prediction of some wheat cultivars productivity in relation to different sowing dates under North Sinai region conditions

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Abstract Two open-field experiments were conducted during 2011/2012 and 2012/2013 seasons at the experimental farm, Faculty of Environ. Agric. Sciences, EL-Arish, Suez Canal 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 sown at three sowing dates (15th October, 15th November, 15th December) 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. Calibration and validation of applying CERES-Wheat model was done through using d-Stat index of agreement between simulated and observed values. Field experiment results indicated that under North Sinai environmental conditions, the significantly highest values of spike length, one thousand kernel weight and radiation use efficiency % were recorded by Gemmeiza-9 cultivar under early sowing date (October, 15). However, the highest values of spike weight, grain yield and dry biological yield were obtained when the same cultivar cultivated under mediate sowing date (mid-November). The output data from the CERES-Wheat model showed that Gemmeiza-9 cultivar recorded the highest observed grain yield in the 1st and 2nd seasons (5352 and 5928 kg ha^{-1}, respectively) and highest predicted grain yield (3957 and 4619 kg ha^{-1}, respectively) in mediate sowing date (mid-November) as compared to other wheat cultivars Misr-1, Sakha-93 and Giza-168. Generally, Gemmeiza-9 under mediate sowing date (November, 15) is recommended treatment to maximized bread wheat grain yield under North Sinai environmental conditions and all similarity regions.

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Introduction

Wheat (*Triticum* ssp.) is the most important food crops in the world and tops the list of cereal crops in terms of area and production. Wheat can be grown under many different topographic and soil situations and is adaptable to extreme weather conditions. Total area planted wheat in the world about 218 million hectares during the 2011/2012 season and is produced about 700 million tons (3.24 ton/ha.) (USDA, 2013) which will control the future of food security of world, 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 problem of such increasable gap especially under the predicted future climatical changes. 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 1.5 °C increase, while this decrease will reach 27% if the increase in temperature is 3.5 °C. Unfortunately, only four percent of 287 thousand feddans reclaimed lands in Egypt with water resources and infrastructures are available in the Sinai and eastern Suez Canal (Hanna and Moustapha, 1995) and consequently adaptable to wheat production. However, 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; FAO, 2003). Due to reduction in tillering period and increased risk of hot weather during grain filling, late planting results in linear reduction in wheat grain yield. Therefore sowing date plays vital role in yield potential of wheat production. The influences of two sowing dates (November, 21th and December, 21th), bread wheat genotype and their interaction on grain yield and yield component characters were investigated by Refay (2011). Results indicated that delayed sowing is associated with substantial losses in grain yield estimated by 7.98% as compared with early and affected number of days to flowering, maturity and grain filling period. Superiority of Gemmeiza-9 cultivar with regard to yield and yield components was investigated by many authors (El-Shami et al., 2000; Hefnawy and wahba, 2003; El-Gizawy, 2005) However, there were differential responses among wheat genotypes to planting dates. In this respect and under North Sinai, Egypt conditions El-Sarag-Eman and Ismaeil (2013) found that the 2nd sowing date (1st December) gave superiority of wheat grain yield and most of its components and Sakha-93 was the potent cultivar in this respect. Meanwhile, Baloch et al. (2010) concluded that sowing wheat on October-25 and November-10 produced the highest number of tillers, spike length, plant height, 1000-grain weight and the grain yield, which subsequently decreased with successive sowing dates. The Decision Support System for Agro-technology Transfer (DSSAT) is a software application program integrating the effects of soil, crop phenotype, weather and management options that allows users to comprise crop simulation models for over 28 crops, as of Version 4.5 (DSSAT.net, 2011). 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). Simulation study using the CERES-Wheat model by Ouda et al. (2005) recommended to plant wheat between 15th of November, and 1st of December, to attain the highest yield. The objectives of this study are to evaluate the performance of some wheat cultivars in relation to meteorological parameters of different sowing dates under El-Arish-North Sinai conditions. Investigation was also extended to evaluate the application of DSSAT-CERES-Wheat model for prediction of growth and yield of wheat under such environmental conditions.

Materials and methods

Field experiments

Two field experiments were conducted at the experimental farm, Faculty of Environ. Agric. Sciences, EL-Arish, Suez Canal University, North Sinai (31° 08′ 04.3″ N, 33° 49′ 37.2″ E) during two seasons of 2011/2012 and 2012/2013. This investigation aimed to evaluate the performance of four bread wheat (*Triticum aestivum* L.) cultivars *i.e.*; Misr-1, Sakha-93, Giza-168 and Gemmeiza-9 under three sowing dates (15th October, 15th November and 15th December). The climatic data of the field experiments, during the growing season of wheat plants in 2011/2012 and 2012/2013 were obtained from El-Arish Agro-meteorological station, Central Laboratory for Agriculture Climate (CLAC, Egypt) and presented in Table 1.

Surface supplementary irrigation during wheat growth period was added as needed. Treatments were arranged in randomized complete block design (RCBD) with four replicates. Sowing dates occupied main plots whereas wheat cultivars were arranged in the sub-plots. Rows spacing were 15 cm apart. Experimental unit area was 10 m^2 and seeding rate was 121.19 kg ha^{-1}. 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. Harvesting dates and accumulated heat units for each sowing dates are shown in Table 2.

Recorded data

(1) Vegetative growth; plant height (cm) and number of tillers/plant.
(2) Yield and its components; spike length (cm), spike weight (g), spike kernel weight (g), 1000-kernel weight (g), number of kernel/spike, dry biological yield (kg/m^2) and grain yield (kg ha^{-1}).
(3) Solar radiation use efficiency (RUE) %.

$$\frac{\textit{Chemical energy of dry biomass}}{\text{Solar radiation energy utilized in photosynthesis}} \times 100$$

(Moursi and Fayed, 1979)

Chemical energy of biomass was estimated in gram calories from dry weight of biomass in gram × 3.7 × 1000. Solar radiation utilized by wheat plants was calculated from total solar radiation along the effective growing period of wheat plant in gram calories × 4200 × 100 × 100. Calculated effective growing period values were different according to sowing dates and wheat cultivars as presented in Table 3.

Table 1 Meteorological data of El-Arish, North Sinai, region during wheat growing season of 2011/2012 and 2012/2013.

Period day (from-to) /month/year	Air. temp. [°C]			Solar radiation [MJ/m^2]	Precipitation [mm]
	Max.	Min.	Aver.		
2011/2012 season					
15–31 October 2011	26.5	16.4	21.6	5.8	0.2
1–15 November 2011	23.9	12.3	18.2	4.3	0.2
16–30 November 2011	19.9	10.4	14.8	4.2	0.2
1–15 December 2011	19.7	7.4	13.3	4.6	0.0
16–31 December 2011	19.7	8.4	13.5	4.3	0.2
1–15 January 2012	17.8	6.9	12.0	4.5	0.0
16–31 January 2012	17.5	7.7	12.2	3.9	0.2
1–15 February 2012	19.1	8.6	13.5	4.9	4.8
16–29 February 2012	19.3	8.1	13.3	6.3	1.4
1–15 March 2012	19.4	9.1	14.2	8.7	0.6
16–31 March 2012	19.9	9.8	14.9	9.0	0.8
1–15 April 2012	25.2	12.4	18.4	10.4	0.2
16–30 April 2012	26.4	14.0	20.2	11.3	0.6
2012/2013 season					
15–31 October 2012	28.2	17.2	22.6	4.1	0.2
1–15 November 2012	26.5	17.2	21.4	2.7	3.4
16–30 November 2012	24.3	12.9	17.9	2.8	2.8
1–15 December 2012	22.2	11.5	16.3	2.7	0.4
16–31 December 2012	20.3	9.6	14.3	2.8	0.8
1–15 January 2013	17.4	7.0	11.8	2.8	2.2
16–31 January 2013	20.3	8.1	13.6	2.5	0.6
1–14 February 2013	20.3	8.8	14.0	3.4	1.6
15–28 February 2013	19.5	10.5	14.8	6.6	0.2
1–15 March 2013	25.4	10.9	17.8	4.8	0.0
16–31 March 2013	23.5	10.5	16.7	5.5	0.0
1–15 April 2013	23.4	12.3	17.6	6.6	0.0
16–30 April 2013	25.1	13.3	19.3	6.2	0.0

Table 2 Harvesting date of wheat plant and its total accumulated heat units along growth season of 2011/2012 and 2012/2013.

Sowing dates	Harvesting date	Accumulated heat units
October, 15	19 March	2493.6
November, 15	30 March	2054.6
December, 15	23 April	1970.8

The computed solar radiation values were provided from the meteorological data of the experimental site in the two respective seasons (Table 1).

Statistical analysis

All data were subjected to statistical analysis for two seasons and their combined using analysis of variance technique (MSTAT-C) computer software package (Russell, 1986) with three replicates. The means values were compared at 0.05 level of probability using Duncan's Multiple Range Test of Mean Separation (Duncan, 1955).

Crop modeling

Results obtained from experimental field studies and the environmental conditions were used as a database 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 was 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

Table 3 The calculated effective growing period values.

Cultivar	Sowing date	Effective growing period (days)	
		2011/2012 season	2012/2013 season
Misr-1	15th October	142	146
	15th November	134	135
	15th December	125	126
Sakha-93	15th October	140	142
	15th November	134	134
	15th December	125	124
Giza-168	15th October	140	142
	15th November	134	134
	15th December	125	124
Gemmeiza-9	15th October	147	148
	15th November	136	137
	15th December	129	130

model was done through using d-Stat index of agreement between simulated and observed values.

Genetic coefficient

Genetic coefficients allow a single wheat crop growth model to predict differences in development, growth, and yield among cultivars when planted in the certain environment. The genetic coefficients can be divided into those that relate to development, to vegetative growth and to reproductive growth.

DSSAT model analyzed the sensitivity of the crop biological responses to changes in the coefficients that relate to phenology. The simulated dates of the phenological stages, and therefore the number of days available for accumulation of grain dry matter, are most sensitive to the photoperiod coefficient (P1D). The sensitivity of the predicted phenology to changes in the vernalization coefficient (P1V), greatly depends on the value of the photoperiod coefficient (P1D). For a particular combination of P1D and the grain filling duration coefficient (P5), the physiological maturity is more sensitive to increases in P1V than the anthesis date. It is important to notice that for certain values of P1D there are an apparent threshold of P1V. The grain filling duration coefficient (P5) does not have any effect on the flowering date, but for values of P5 above 1.5 there is an increase in the number of days between emergence and physiological maturity. Increases in P5 increase the grain filling period.

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. Evaluation of the derived cultivar coefficients was conducted with time series growth data collected from experiments grown during the two seasons. Definitions of the coefficients are provided in Table 4. The coefficients P1V, P1D and P5 were calibrated, so the observed and simulated phenological dates were as close as possible:

Evaluation of applying DSSAT-CERES-Wheat model

There are different statistic indexes that comes with the model output files, including, the normalized root mean square error (RMSE) that is expressed in percent, calculated as explained by Loague and Green (1991) with the help of following equation:

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}} \times \frac{100}{M}$$

where

n number of observations.
Pi *and* Oi predicted and observed values, respectively.
M the observed mean value.

RMSE gives a measure (%) of the relative difference of simulated vs. observed data. The simulation is considered excellent with RMSE < 10%, good if 10–20%, fair if 20–30%, poor > 30% (Jamieson et al., 1991). For yield and yield components, the mean square error (MSE) was calculated into a systematic (MSEs) and unsystematic (MSEu) component as it is explained by Willmott (1981). The Index of Agreement (d) as described by Willmott et al. (1985) was estimated as shown in the following equation:

$$d = 1 - \left[\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}(|P'_i| + |O'_i|)^2}\right]$$

where

n the number of observations.
Pi the predicted observation.
Oi measured observation.
$P'i$ = Pi −M.
$O'i = Oi - M$ (M is the mean of the observed variable).

Therefore, if the d-statistic value is closer to one, then there is good agreement between the four cultivars that are being compared and *vice versa*. So it is very important that if value varies from value of one then there will be weak agreement of the variable that we are being compared with each other.

Using the sensitivity analysis option of the model, the cultivar coefficients of the four cultivars were adjusted by minimizing RMSE values between observed and simulated flowering and physiological maturity dates, vegetative growth, yield and yield components. Correlation analysis for harvest index between observed and simulated output values were obtained using the standard error of the "Excel- Microsoft" program.

Result and discussions

Field experiments

The interaction between sowing dates and wheat cultivars on growth, yield, yield components and RUE criteria under

Table 4 The genetic coefficient values for the studied bread wheat cultivars.

Coefficients	Definition	Cultivar			
		Misr1	Sakha93	Giza168	Gemmeiza-9
P1V	Days at optimum vernalizing temperature required to complete vernalization.	0.5	0.5	0.5	0.5
P1D	Percentage reduction in development rate in a photoperiod 10 h shorter than the threshold relative to that at the threshold.	100	100	100	100
P5	Grain filling (excluding lag) phase duration (°C.d).	510	510	510	630
G1	Kernel number per unit canopy weight at anthesis (#/g).	21	28	30	28
G2	Standard kernel size under optimum conditions (mg).	30	25	30	25
PHINT	Phylochron interval; the interval in thermal time (degree days) between successive leaf tip appearances.	95	120	85	130

North Sinai environmental conditions in both 2011/2012, 2012/2013 seasons and their combined were investigated.

Data presented in Table 5 showed no significant impacts for the interaction on the following characters: Plant height, number of tillers/plant and spike kernel weight in both seasons and their combined and spike length, 1000-kernel weight, and dry biological yield in the 1st season as well as spike weight and RUE in both 1st and 2nd seasons. These results reveal that both sowing date and cultivars in each assessment act independently on the above mentioned characters. Significant impacts of such interaction on certain characters in the two experimental seasons and their combined will be presented in Tables 6–11 and discussed as follows.

Spike length (cm)

Interaction between sowing dates and wheat cultivars exerted a significant effect on spike length in both the 2nd season and the combined analysis (Table 6). Gemmeiza-9 cultivar under early sowing date (October, 15) gave the significantly tallest spike length (14.20 cm) in the second season and (14.18 cm) in combined. Delay planting date led to gradual decrease in spike length for all cultivar tested. Meanwhile, the shortest spike length was achieved in both 2012/2013 season and the combined from the delaying sowing of Misr-1 cultivar. Differences in spike length values between shortest spike length of Misr-1 and all other cultivars under late sowing date (December, 15) were not great enough to reach the 5% level of significance. This trend was the true either in the 2nd season or in the combined analysis.

Spike weight (g)

Under climatic conditions of North Sinai wheat spike weight was significantly affected by the interaction between sowing dates and cultivars in combined analysis. Highest values of spike weight were produced from Gemmeiza-9 cultivar under mediate sowing date (mid-November). However, spike weight value of such potent interaction treatment (3.82 g) was in par with those obtained from the same cultivar (Gemmeiza-9) under early (3.69 g) and lately (3.39 g) sowing dates. Similarly, highest value of Misr-1 cultivar spike weight (3.26 g) was produced under mediate sowing date (mid-November). Meanwhile, Sakha-93 and Giza-168 cultivars gave their potency under early sowing date (3.51 and 3.33 g, respectively).

Table 5 Significance of the interaction between sowing dates and wheat cultivars on growth, yield components, grain yield and RUE % traits of wheat under North Sinai environmental conditions in both 2011/2012 and 2012/2013 and their combined.

Traits	2011/2012	2012/2013	Combined
Vegetative characters			
Plant height (cm)	N.S	N.S	N.S
Number of tillers/plant	N.S	N.S	N.S
Yield and its components			
Spike length (cm)	N.S	**	**
Spike weight (g)	N.S	N.S	**
Spike kernel weight (g)	N.S	N.S	N.S
1000-kernel weight (g)	N.S	**	**
Dry biological yield (kg m^{-2})	N.S	*	**
Grain yield (ton fed^{-1})	**	**	**
Radiation use efficiency (RUE)	N.S	N.S	*

Means having the same letter within each factor are not significantly differed at 0.05 level, according to Duncan's multiple range test.

Table 6 Effect of the interaction between sowing dates and wheat cultivars on spike length (cm) under North Sinai environmental conditions in 2012/2013 and their combined.

Sowing dates	Cultivars			
	Misr-1	Sakha-93	Giza-168	Gemmeiza-9
2012/2013 season				
October, 15	13.40 b	13.53 ab	13.00 bc	14.20 a
November, 15	12.20 de	12.33 cde	12.93 bcd	12.53 cde
December, 15	11.00 g	11.60 ef	11.20 fg	11.90 ef
Combined				
October, 15	13.38 bc	13.51 b	13.31 bc	14.18 a
November, 15	12.80 c	11.90 d	13.23 bc	12.90 bc
December, 15	11.13 e	11.48 de	11.23 e	11.72 de

1000-kernel weight (g)

Data obtained in Table 8 revealed the significant effect of interaction between planting dates and wheat cultivars on wheat seed index in the 2nd season and the combined. Generally, it could be concluded that 1000-kernel weight of all the studied four cultivars were progressively decreased by delaying sowing date. This trend was fairly true either in the 2nd season or the combined. Highest value of seed index was recorded with early sowing of Gemmeiza-9 cultivar. One thousand kernel weight value of such potent interaction treatment was exceeded significantly all the other studied interaction treatments in this respect.

Seed index of the studied cultivars was remarkably differed in their depression response befell by delaying sowing date. Estimated reductions in 1000-kernel weight values by delaying sowing dates from October, 15 to December, 15 in combined were 8.9% for Misr-1; 15.2% for Sakha-93; 0.1% for Giza-168 and 21.9% for Gemmeiza-9. Such finding clear that the highest reduction in seed index was carried out for the potent Gemmeiza-9 cultivar irrespective to its insignificant superiority than the other tested cultivar in late sowing date. Slight depression value of Giza-168 indicates the high flexibility of the cultivar to sowing date and its suitability to late sowing with respect to such trait.

Dry biological yield (kg/m^2)

Wheat dry biological yield was significantly governed by the interaction between sowing dates and cultivars in the 2nd season and combined analysis (Table 9).

Table 7 Effect of the interaction between sowing dates and wheat cultivars on spike weight (g) under North Sinai environmental conditions (combined analysis).

Sowing dates	Cultivars			
	Misr-1	Sakha-93	Giza-168	Gemmeiza-9
October, 15	2.84 def	3.51 abc	3.33 a-e	3.69 ab
November, 15	3.26 b-f	2.78 ef	2.90 def	3.82 a
December, 15	2.04 f	2.32 ef	2.16 f	3.39 a-d

Table 8 Effect of the interaction between sowing dates and wheat cultivars on 1000-kernel weight (g) under North Sinai environmental conditions in 2012/2013 season and combined analysis.

Sowing dates	Cultivars			
	Misr-1	Sakha-93	Giza-168	Gemmeiza-9
2012/2013 season				
October, 15	52.07b-e	57.40 b	55.33 bc	63.47 a
November, 15	50.42 cde	54.55 bc	50.28 cde	55.58 bc
December, 15	47.51 de	49.77 cde	46.82 e	53.71 bcd
Combined				
October, 15	52.12 cd	57.33 b	46.82 d	63.49 a
November, 15	50.90 cd	49.34 d	48.30 d	55.68 bc
December, 15	47.48 d	48.60 d	46.77 d	49.59 d

Table 9 Effect of the interaction between sowing dates and wheat cultivars on dry biological yield (kg/m^2) under North Sinai environmental conditions in 2012/2013 season and combined analysis.

Sowing dates	Cultivars			
	Misr-1	Sakha-93	Giza-168	Gemmeiza-9
2012/2013 season				
October, 15	1.73 ab	1.55 abc	1.47 abc	1.54 abc
November, 15	1.32 bc	1.70 ab	1.51 abc	1.87 a
December, 15	1.23 c	1.13 c	1.14 c	1.45 abc
Combined				
October, 15	1.45 cd	1.30 d	1.28 d	1.80 ab
November, 15	1.35 d	1.67 abc	1.52 bcd	1.93 a
December, 15	1.29 d	1.203 d	1.22 d	1.32 d

Obtained results show that mediate sowing date (mid-November) favored vegetative growth of Gemmeiza-9 cultivar to produce the significantly highest value of dry biological yield. This finding was fairly true in both the second season and the combined (1.87 and 1.93 kg m^{-2}, respectively). However, no significant difference was detected between dry biological yield of Gemmeiza-9 either in mediate sowing date (mid-November) or in early sowing date (mid-October) in combined analysis. On the contrary, the lowest values of wheat dry biomass were recorded in the 2nd season and combined with lately sowing of sakha-93 and Giza-168 cultivar plants. Mediate sowing date (mid-November) seem to be more suitable sowing date for the two previous cultivars either in the 2nd season or in combined analysis to produce the optimum vegetative growth and consequently their highest values of dry biomass comparing with their early (mid-October) or lately (mid-December) sowing dates. Differences between dry biological yields of Misr-1 cultivar in the different sowing dates in the combined were not significant. Such finding verified that dry biological yield of Misr-1 cultivar was not profoundly governed by date of planting.

Radiation use efficiency (RUE) %

Radiation use efficiency assessment was significantly influenced by the interaction only in the combined analysis (Table 10). Available results indicate that the highest value of RUE (2.56) was achieved by Gemmeiza-9 cultivar sown at mid-October. However mediate sowing date (mid-November) of the same cultivar recorded insignificant equivalent value (2.33) for such trait. Delaying sowing date for such potent cultivar to be mid-December decreased its RUE value by 25.4 and 18% than those of early and mediate planting date, respectively. Radiation use efficiency (RUE) of a crop is a function of several interacting physiological phenomena, each of which can be tackled independently from the point of view of genetic improvement. In this connection Reyonald et al. (2000) reported that improved RUE will be partly a function of genotype's ability to buffer itself against changes in its environment to match the demand imposed by its development. Otherwise, Edwards (2005) showed that radiation use efficiency (RUE) varied from 1.98 to 2.79 g Mj^{-1} among winter wheat cultivars in the southern Great Plains and had the greatest impact on fall wheat biomass production.

Available collected data in Table 10 show the clear reduction in RUE value of Misr-1 and Giza-168 cultivars also by delaying sowing date from mid-October to mid-December which amounted to 22.2% and 13.4%, respectively. Likewise, Sakha-93 gave the highest RUE value at mediate sowing date (mid-November) and also decreased by about 15.9% by delaying date of sowing to mid-December. Variation in RUE values between wheat cultivars under different meteorological conditions was also reported by Miralles and Slafr (1997), Edwards (2005), Miranzadeh et al. (2011), and Sun et al. (2013).

Grain yield (ton/fed.)

Obtained results in Table 11 indicated that grain yield (ton/fed) was significantly governed by the studied interaction either in both the two experimental seasons (2011/2012 & 2012/2013) or the combined analysis. Gemmeiza-9 cultivar planted in mediate sowing date (mid-November) achieved the highest values of grain yield. This finding was true in either 1st and 2nd seasons or the combined (2.23, 2.47 and 2.35 ton/fed., respectively). However, grain yield of such interacted treatment was at par with that yielded by the same cultivar under early sowing date (mid-October,) in the 1st and 2nd seasons. Delaying sowing date for such potent cultivar to be mid-December decreased its grain yield value in the 1st and 2nd seasons and combined by 39.5%, 44.5% and 42.98%, respectively.

Misr-1 cultivar produced its highest value of grain yield under mediate sowing (mid-November) either in 1st and 2nd seasons or the combined (2.01, 1.53 and 1.77 ton/fed, respectively). However, Sakha-93 was in the same trend of each Misr-1 and Gemmeiza-9 cultivars in the 2nd season in order

Table 10 Effect of the interaction between sowing dates and wheat cultivars on radiation use efficiency % of wheat plants under North Sinai environmental conditions (combined analysis).

Sowing dates	Cultivars			
	Misr-1	Sakha-93	Giza-168	Gemmeiza-9
October, 15	2.07 bc	1.88 cde	1.87 cde	2.56 a
November, 15	1.61 e	2.01 bcd	1.85 cde	2.33 ab
December, 15	1.87 cde	1.69 de	1.62 e	1.91 cde

Table 11 Effect of the interaction between sowing dates and wheat cultivars on grain yield (ton/fed.) of wheat plants under North Sinai environmental conditions (2011/12 and 2012/13 seasons and combined analysis).

Sowing dates	Cultivars			
	Misr-1	Sakha-93	Giza-168	Gemmeiza-9
2011/2012 Season				
October, 15	1.23 de	1.85 abc	1.29 de	1.83 abc
November, 15	2.01 ab	1.59 bcd	1.54 cd	2.23 a
December, 15	1.05 e	1.21 de	1.23 de	1.35 de
2012/2013 Season				
October, 15	1.24 e	1.83 bcd	2.15 ab	1.87 bcd
November, 15	1.53 de	2.11 abc	1.31 e	2.47 a
December, 15	1.30 e	1.60 cde	1.27 e	1.37 e
Combined				
October, 15	1.238 e	1.843 b	1.723 bc	1.852 b
November, 15	1.772 b	1.662 bc	1.432 cde	2.352 a
December, 15	1.175 e	1.403 bcd	1.250 e	1.335 de

to its highest grain yield in mediate sowing date (mid-November). Whereas, Giza-168 cultivar obtained its highest grain yield value (2.15 ton/fed) under early planting date (mid-October) in the 2nd season. Moreover, grain yield of such interacted treatment was at par with that yielded by the same cultivar under early sowing date (mid-October) and under mediate sowing date (mid-November) in the combine. On the contrary, delaying sowing date for each of the studied cultivars ordinarily decreased the grain yield. In this connection, the lowest grain yield was provided by Misr-1 cultivar (1.05 ton/fed) in the 1st season. Differences between grain yields of Misr-1 cultivar and each of Sakha-93 and Giza-168 in lately sowing date (mid-December) were not great enough to reach 5% level. Such finding verified that grain yield of all the studied wheat cultivars was sensitively affected by lately planting.

Generally, one could deduce that yield and yield components of all the studied wheat cultivars were decreased by delaying sowing date (mid-December). Calculated accumulation heat unites (from sowing to harvest) were progressively decreased by delaying sowing date. For example the calculated heat units for 1st, 2nd and 3rd sowing dates in the 2nd season were 2493.6, 2054.6 and 1970.8 units, respectively (Table 2). Such values sustained that accumulated heat units of the late sowing may be not sufficient for completing phenological stages of wheat growth and exerted such depression in growth and productivity of wheat plant. Likewise, delaying sowing date conspicuously shortening growing season of wheat plant (Table 3) and consequently diminished their capacity for utilizing available environmental elements and achieved the lowest yield and yield component values. Similar results were reported by Sial et al. (2005) and Baloch et al. (2010).

Variation in wheat cultivars grain yield under different sowing dates was also reported by El-Shami et al. (2000), Hammad and Abd El-Aty (2007), Feltaous (2009), Ali et al. (2010), and El-Sarag-Eman and Ismaeil (2013). In this respect Hammad and Abd El-Aty (2007) indicated that Sakha-8, Sids-1, Sids-4, Sakha-61 and Gemmeiza-9 cultivars gave their highest grain yield, grains/spike, and No. tillers/m^2 when seeded at November 10th. The percentage reduction in grain yield after November 10th planting date was calculated as 14.45%, 24.26%, 36.71% and 48.04% from crop planted on November 25th, December 10th, December 25th and Jan. 10th, respectively. Likewise, Ali et al. (2010) stated that three years results concluded that regardless of the varieties, November 10th to November 20th is the optimum sowing date for wheat.

Crop model

The CERES-Wheat model was used to quantify variability in wheat growth and grain yield over the two seasons, 2011/2012 and 2012/2013 in North Sinai (El-Arish) region conditions. The model simulated growth and grain yield of the four cultivars (Misr-1; Sakha-93; Giza-168 and Gemmeiza-9) and the three sowing dates (15th October; 15th November and 15th December). Daily weather data, soil profile properties, soil profile initial conditions, irrigation management data, crop management data and genetic coefficients of wheat as described in the materials and methods. DSSAT-CERES-Wheat Model was validated and evaluated by d-Stat between observed values of field measurements and predicted values obtained by the model.

Number of days from sowing to anthesis

Data presented in Table 12 showed the comparison between observed and predicted number of days from sowing to anthesis date of wheat plant in the two experimental seasons, 2011/2012 and 2012/2013 under North Sinai (El-Arish) environmental conditions.

It will be necessary to clarify that the CERES-Wheat model was calculated the number of days from sowing to anthesis using the input Agro-meteorological data on the basis of optical-clocks received by the plant and not the days recorded. Anthesis date results indicated that the output data from the CERES-Wheat model were in harmony with the observed data in both seasons (2011/2012 & 2012/2013) of the experiment. Differences in number of days from sowing to anthesis due to sowing dates effect in both results of observed and predicted data, Misr-1; Sakha-93 and Giza-168 cultivars under lately sowing date (mid-December) had earlier flowering as compared to Gemmeiza-9 cultivar. Whereas, earlier sowing date

Table 12 Observed and predicted number of days from sowing to anthesis four bread wheat cultivars as affected by different sowing dates in 2011/2012 and 2012/2013 seasons.

Seasons		2011/2012			2012/2013		
Cultivar	Sowing date	Days to anthesis			Days to anthesis		
		Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*
Misr-1	October, 15	112	119	0.913	114	116	0.964
	November, 15	95	101		93	98	
	December, 15	88	98		89	91	
Sakha-93	October, 15	112	119	0.907	113	115	0.953
	November, 15	94	102		92	99	
	December, 15	89	97		88	90	
Giza-168	October, 15	112	119	0.913	113	115	0.955
	November, 15	94	101		92	99	
	December, 15	88	97		88	90	
Gemmeiza-9	October, 15	115	122	0.951	116	127	0.976
	November, 15	96	105		95	101	
	December, 15	90	95		91	93	

* Index of agreement (d-Stat) as described by Willmott et al. (1985).

(mid-October) prolonged the observed and predicted number of days to anthesis for all wheat cultivars in 2011/2012 and 2012/2013 seasons. The CERES-wheat model was predicted that Gemmeiza-9 cultivar was having longest number of days to anthesis as compared to Misr-1, Giza-168 and Sakha-93 cultivars. The d-Stat index of agreement, as absolute values, between observed and predicted number of days to anthesis for the 1st season was from 90.7% to 95.1% and from 95.5% to 97.6% for 2nd season.

These results may refer to minimum and maximum temperature that cause to a reduction in growing cycle length of wheat for all cultivars under North Sinai (El-Arish) environmental conditions. Simulation ability of the model was similar to what obtained by Ouda et al. (2005) and Hassanein and Medany (2007). In this respect, Hassanein et al. (2012) showed that Gemmeiza 9 cultivar gave the longest observed and predicted number of days for anthesis date. Sakha 93 cultivar gave the shortest observed and predicted number of days for anthesis date. Also, Abdul Haris et al. (2013) showed 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

Obtained results in Table 13 dealing with the differences in number of days from sowing to physiological maturity due to sowing dates and cultivars in both results from observed and predicted data indicate that, Gemmeiza-9 cultivar was the latest cultivar to reach the physiological maturity as compared with Misr-1; Sakha-93 and Giza-168 cultivars in the earliest sowing dates (mid-October) for observed data by 1.9% in the 1st season. Gemmeiza-9 was needed longest observed period (155 d) to reach the physiological maturity stage but, the length of growing cycle was reduced by 1.29% when Misr-1 cultivar sown

Table 13 Observed and predicted days from sowing to physiological maturity of four bread wheat cultivars as affected by different sowing dates in 2011/2012 and 2012/2013 seasons.

Season		2011/2012			2012/2013		
Cultivar	Sowing date	Days to physiological maturity			Days to physiological maturity		
		Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*
Misr-1	October, 15	151	160	0.921	153	155	0.912
	November, 15	134	146		131	141	
	December, 15	127	138		128	127	
Sakha-93	October, 15	151	161	0.925	152	156	0.926
	November, 15	133	147		130	142	
	December, 15	128	137		127	129	
Giza-168	October, 15	151	160	0.925	152	155	0.926
	November, 15	133	146		130	142	
	December, 15	127	137		127	129	
Gemmeiza-9	October, 15	154	163	0.902	155	156	0.891
	November, 15	135	139		133	137	
	December, 15	129	134		130	127	

* Index of agreement (d-Stat) as described by Willmott et al. (1985).

Table 14 Simulated and observed grain yield (kg ha^{-1}) of four bread wheat cultivars as affected by different sowing dates in 2011/2012 and 2012/2013 seasons.

Seasons		2011/2012			2012/2013		
Cultivars	Sowing date	Grain yield (kg ha^{-1})			Grain yield (kg ha^{-1})		
		Observed	Predicted	d-Stat*	Observed	Predicted	d-Stat*
Misr-1	October, 15	2952	2191	0.658	2976	3079	0.971
	November, 15	4824	3880		3672	3584	
	December, 15	2520	1749		3120	3031	
Sakha-93	October, 15	4440	3943	0.84	4392	3615	0.732
	November, 15	3816	3166		5064	4534	
	December, 15	2904	2753		3840	3046	
Giza-168	October, 15	3096	2133	0.763	5160	4294	0.756
	November, 15	3696	2419		3144	4005	
	December, 15	2952	1471		3048	3224	
Gemmeiza-9	October, 15	4392	3062	0.727	4488	3603	0.716
	November, 15	5352	3957		5928	4619	
	December, 15	3240	2686		3288	2817	

* Index of agreement (d-Stat) as described by Willmott et al. (1985).

in mid-October sowing date. Whereas, Sakha-93 and Giza-168 was needed the shortest observed period (152 d) to reach the physiological maturity stage in the 2nd season. However, the prevailing climatic condition in the latest sowing date (mid-December) compelled Misr-1 and Giza-168 cultivars to reach the physiological maturity early as compared to Gemmeiza-9 cultivar for observed data in the 1st season by 1.55%.

These results may clarify that late sowing provides shorter period for the vegetative growth and compels the wheat cultivars to complete its life cycle earlier. Simulation ability of the model was similar to what obtained by Ouda et al. (2005) and Hassanein and Medany (2007). In this respect, Hassanein et al. (2012) showed that Gemmeiza-9 cultivar gave the longest observed and predicted number of days for physiological maturity date at different sowing dates and Misr-1 cultivar gave the shortest observed and predicted number of days for physiological maturity date. Whereas, effects of climate factors on crop growth stages and development inter-related within specific pattern. Meteorological conditions before and after flowering will influence to wheat yield and production (Yu et al., 2013).

The d-Stat index of agreement, as absolute values, between observed and predicted number of days from sowing to physiological maturity date in 2011/2012 season was from 90.2% to 92.5% and was from 89.1% to 92.6% for 2012/2013 season.

Grain yield at maturity

Table 14 shows the data of observed and predicted grain yield at maturity (kg ha^{-1}) in the two experimental seasons (2011/2012 and 2012/2013) under North Sinai (El-Arish) environmental conditions.

Regarding to changing sowing dates and the effect of varietal differences among four wheat cultivars results indicate that the output data from the CERES-Wheat model (predicted data) were different with the observed data (Table 14). The d-Stat index of agreement, as absolute values, between observed and predicted grain yield at maturity in the 1st season was from 65.8% to 84% and from 71.6% to 97.1% in the 2nd season.

Gemmeiza-9 cultivar recorded in the 1st season the highest observed and predicted grain yield (5928 and 3957 kg ha^{-1}, respectively) in mediate sowing date (mid-November) and exceeded other wheat cultivars Misr-1, Sakha-93 and Giza-168 in observed grain yield by 9.87%, 28.69% and 30.94%, respectively, while for predicted grain yield by 1.95%, 19.9% and 38.9%, respectively. On the contrary, Sakha-93 cultivar produced its highest observed and predicted grain yield under earliest sowing date (mid-October) in the 1st season (4440 and 3943 kg ha^{-1}, respectively). However, the observed and predicted values of grain weight in the 2nd season are in par with those obtained from the 1st season. Mediate sowing date (November, 15) showed the superiority of observed and predicted grain yield at maturity. Whereas, Gemmeiza-9 cultivar exceeded all other wheat cultivars Misr-1 Sakha-93 and Giza-168 in observed grain yield by 38.05%, 14.57% and 46.96%, respectively and in predicted grain yield by 22.4%, 1.84% and 13.29%, respectively.

It is important to note that the results of simulation study using the CERES-Wheat model under DSSAT interface are in trend with those obtained from field experiment particularly in grain yield (Table 11). Under environmental conditions of North Sinai the late sowing provide shorten growth period for the wheat cultivars (Table 13) and hence confirms negative correlation between sowing dates and grain yield. Simulation ability of the model was similar to what obtained by Ouda et al. (2005), Hassanein and Medany (2007), and Hassanein et al. (2012). Whereas, Yano et al. (2007) describe through a simulation study the effects of climate change on crop growth for a wheat cropping sequence in Turkey for the period of 1990 to 2100. They suggested that the temperature rise accelerated crop development but shortened wheat growing period by 24 days and increase by 16 and 36% in grain yield.

Conclusion

Field experiment results indicated that under North Sinai environmental conditions, the significantly highest values of spike length, one-thousand kernel weight and radiation use efficiency % were recorded by Gemmeiza-9 cultivar under early sowing date (October, 15). However, the highest values of spike weight, grain yield and dry biological yield were obtained when the same cultivar cultivated under mediate sowing date (mid-November). The output data from the CERES-Wheat model showed that Gemmeiza-9 cultivar recorded the highest observed grain yield in the 1st and 2nd seasons (5352 and 5928 kg ha^{-1}, respectively) and highest predicted grain yield (3957 and 4619 kg ha^{-1}, respectively) in mediate sowing date (mid-November) as compared to other wheat cultivars Misr-1, Sakha-93 and Giza-168. So, it is necessary to note that the investigation results generally concluded that growing Gemmeiza-9 under mediate sowing date (November, 15) is recommended to maximize bread wheat grain yield under North Sinai environmental conditions and all similarity regions.

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