Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURE SCIENCES JOURNAL
Volume 3, Issue 2, 2020, Pages 255–272
Available online at www.agricuta.edu.eg
DOI: https://dx.doi.org/10.21608/aasj.2020.211507

Evaluating DSSAT program for simulating wheat yield production with different irrigation and nitrogen applications under Upper Egypt conditions

Gameh M. A.[a], Ahmed E. M.[a], Dardiry M. R.[b], Elmahdy A. M. [b*]

[a] *Soil Science Department, Faculty of Agriculture, Assiut University, Assuit, Egypt*
[b]*Water Requirements and Field Irrigation Department, Soil, Water and Environment Research Institute, ARC, Giza, Egypt*

Abstract

The overall objective of this work was to study the irrigation scheduling effects on the productivity of irrigated wheat in relation to mineral organic nitrogen fertilization, including initial testing of the DSSAT v4.7.0.0 model. In order that, a field experiment was conducted under Upper Egypt conditions in El-Mattana Agricultural Research Station, Luxor governorate, Egypt. The data of irrigation scheduling ((I1) 1.2, (I2) 1.0 and (I3) 0.8 pan evaporation coefficient) and mineral organic nitrogen fertilization program ((F1) 75 kg N fed^{-1} as compost, (F2) 75%N as compost + 25% N as mineral, (F3) 50% N as compost + 50% N as mineral (F4) 25%N as compost + 75% N as mineral and (F5) 75 kg N feddan^{-1} as urea) (feddan = 4200 m² = 0.420 hectares = 1.037 acres) during the two studied seasons 2016/17 and 2017/18, were used for model calibration and validation. Model evaluation results showed a closer relationship between CERES-DSSAT and observed wheat grain yield at both seasons. The values of relative root mean square error (RRMSE), coefficient of residual mass (CRM) and index of agreement (d-stat) were 6.6, 9.6 and 0.90 in the 1st and 3.9, 1.7 and 0.92 in the 2nd season, respectively. So, it could be concluded that the model works well under Upper Egypt condition, thus, studying the impacts of different management and climate change can be applied.

Keywords: DSSAT, scheduling, irrigation, evaporation pan.

*Corresponding author: Elmahdy A. M.,
E-mail address: ahm_elmahdy@yahoo.com

1. Introduction

Water is the most important factor in crop production. About 85% of total water resources in Egypt are consumed by the agricultural sector. Always, water scarcity is the focal point for the most agronomists and on-farm irrigation specialists. The basic work for irrigation water allocation in regional scales is to guarantee the crop yield with limited irrigation water at farm scale. Therefore, irrigation should be accurately timed and quantified, *i.e*., there must be a robust irrigation scheduling program that ensures minimizing non-productive soil water by evapo-transpiration or drainage losses (Arora and Gajri, 1998). There are many methods and tools used in irrigation scheduling. The World Meteorology Organization (WMO) recommended the Class A evaporation pan for evaporation measurements since it is easy to use and relatively inexpensive (Stanhill, 2002). Agronomists have used the evaporation pan method for irrigation scheduling, and it was proven to save up to 20% of the applied irrigation water by farmers under Egyptian conditions (Khalil *et al*., 2009). It is an open pan of water that is subjected to the same climatic conditions with the grown crop, and from which water is evaporated (by wind speed, air temperature, relative humidity and net radiation) as a result of the climatic conditions (Smajstrla *et al*., 2000). Egypt territory located at the band of dry and semi-arid regions. In general, soils of Egypt characterized by poverty in organic matter content so total nitrogen with less than two percent. However, few studies have been conducted on the use of manures and biofertilizers for agriculture production (FAO, 2005). Continuous application of chemical fertilizers causes soil health problems even if applied in a balanced proportion (Zia *et al*., 2000). This is mainly due to the quick hydrolysis of chemical fertilizer (Farhad *et al*., 2013). Also, they pollute our environment as well as kills beneficial soil microorganisms (Noreen and Noreen, 2012). On the other hand, organic matter addition plays a major role in soil fertility: nutrients storage, increasing CEC, improving soil structural stability, fauna stimulation and microbial & enzymatic activities (Feller, 1995). Also, it improves soil physical properties and increasing the soil water holding capacity (Chandra, 2005). Integrated nutrient management is essential for proper plant growth, water use, soil and land management, which will be critical for the sustaining agriculture productivity over the long term. The overall strategy for increasing crop yields and sustain their high production must include an integrated approach of soil nutrients. An integrated approach recognizes that soils are the storehouse of most essential nutrients for plant (Shah *et al*., 2010). Concerning this vision, many scientists like Shah and Ahmed (2006), Shah *et al*. (2010) and Koushal *et al*. (2011) recommended that applying N as a mineral and organic form in 75:25 or 50:50 ratios of basis N would be profitable for wheat productivity and sustainable soil fertility. Crop models allow researchers and agricultural investors to get well-informed research and crop management decisions (Jones *et al*., 2003). The DSSAT is a computer program consists of modules for the growth and development of different crop types, soil water balance, soil organic matter & nitrogen, crop residues, soil phosphorous, soil pH, soil erosion, and crop management. The crop 'Manager' module allows the user to interact directly with program variables that affect field management operations (sowing, applying fertilizer, irrigation, harvesting) and also to track the values of system variables as well as calculate additional derived values (Jones, 2013). CERES-Wheat is one of the various DSSAT program windows. Simulates crop development, growth and partitioning assimilates various plant parts as a function of environmental factors such as soils, weather and crop characteristics. Phenological development and growth of a crop are specified in DSSAT by cultivar-specific genetic coefficients (Hoogenboom *et al*., 2004). The DSSAT has not yet applied under Upper Egypt condition, and to recommend it for the public use, a deliberated calibration and validation are required, then comparing model simulations with close data observations from actual experiment yields. After that, a more detailed analysis of crop performance can be conducted for different management (soil, plant, irrigation and fertilizer strategies) and climate change to determine the most promising and least risky practice. So, in this study, Cropping System Model CERES-Wheat of DSSAT 4.7 software was evaluated using irrigation and nitrogen practices that attain the highest wheat yield under the implemented experimental conditions of Upper Egypt.

2. Materials and Methods

A field experiment was conducted at El-Matteana Agricultural Research Station, Luxor governorate, Upper Egypt during winter wheat growing seasons of 2016/17 and 2017/18.

2.1 Climatic characteristics prevailing

Monthly means of maximum, minimum and average temperature (^oC), relative humidity (%), wind speed (m/sec), rainfall (mm) and possible sunshine duration (hours/day) for the experimental site during two growing seasons of 2016/17 and 2017/18 are presented in Table (1).

Table (1): Meteorological data for El-Mattana Agricultural Research Station, Luxor, Egypt during wheat growing seasons of 2016/17 and 2017/18.

Month	Temperature means maximum (°C)	Temperature average (°C)	Temperature means minimum (°C)	Relative humidity (%)	Wind speed 2m (m/sec)	Rainfall (mm)	Sunshine duration (hr)
2016/17							
November	30.2	22.8	15.3	46.8	0.3	0.0	10.8
December	22.5	15.3	8.1	53.6	0.3	0.0	11.1
January	22.0	14.6	7.1	46.8	0.3	0.0	11.3
February	22.9	15.5	8.0	44.0	0.7	0.0	11.2
March	27.5	20.1	12.6	37.7	0.7	0.0	11.9
April	34.3	26.4	18.5	30.7	0.8	0.0	12.6
Average	26.6	19.1	11.6	43.3	0.5	0.0	11.5
2017/18							
November	27.9	20.6	13.1	40.9	0.5	0.0	10.8
December	26.1	18.6	11.3	46.0	0.8	0.0	10.7
January	22.3	14.5	7.0	43.6	0.7	0.0	10.6
February	28.1	19.5	11.1	34.3	1.3	7.4	11.2
March	33.8	24.8	15.9	28.7	1.0	0.0	11.9
April	35.0	26.7	18.5	29.6	1.3	0.0	12.5
Average	28.9	20.8	12.8	37.2	0.9	1.2	11.3

Source: Central Laboratory for Agricultural Climate, Giza Egypt.

2.2 Soil properties of the experimental site

Physical and chemical properties of the experimental field are presented in Table (2).

2.3 The biological experiment

Wheat seeds MISR2 (*Triticum aestivum L.*) were sown on 27th of November 2016 and repeated in the same date in 2017. The experimental design was split plot design with 3 irrigation regimes and 5 N fertilization schedule in 3 replications. The main plot area represented irrigation scheduling. Each main plot was divided into 5 sub-plots that received N fertilizer regimes. The total number of the experimental plots was 45 plots Table (3). Chemical and physical analyses of added compost are presented in Table (4).

Table (2): Physical and chemical properties of the experimental field.

Properties	Value		Method employed
	2016/17	2017/18	
Soil texture	Clay loam		International pipette method (Piper, 1966).
Soil pH	7.75	7.79	(1:2.5, soil: water) pH meter instrument (Brower and Zar, 1984)
EC (dS/ m at 25ºC)	1.3	1.28	(1:5, soil: water) electrical conductivity meter (Rowell, 1994)
$CaCO_3$ (%)	3.5	4.1	Collins Calorimeter (FAO, Soil Bulletin 38/2, 1980)
Available N(ppm)	57	55	(NH_4^+) + (NO_3^-) (FAO, 2008)
Available P (ppm)	10.4	11	0.5 M Na HCO3 at pH 8.2 (FAO, 2008)
Available K (ppm)	282	278	Photometric method (FAO, 2008)

Source: Central Laboratory for Agricultural Climate, Giza Egypt.

Table (3): The studied factors and their treatments.

Factor	Treatment	Legend
Irrigation scheduling	1.2 pan evaporation coefficient	I1
	1.0 pan evaporation coefficient	I2
	0.8 pan evaporation coefficient	I3
Fertilization levels	75 kg N fed^{-1} as compost (100% organic)	F1
	75%N as compost + 25% N as mineral	F2
	50% N as compost + 50% N as mineral	F3
	25%N as compost + 75% N as mineral	F4
	75 kg N fed^{-1} as urea (100% mineral)	F5
Treatments	(I1F1, I1F2, I1F3, I1F4 and I1F5), (I2F1, I2F2, I2F3, I2F4 and I2F5) and (I3F1, I3F2, I3F3, I3F4 and I3F5)	

Table (4): Chemical and physical analysis of added compost.

Properties	2016/17	2017/18	Method employed
Weight /M^3(Kg)	520	500	
Moist content (%)	30	27	Dried at 70 ºC to constant weights (Page *et al.*, 1982)
PH (1:10)	8.5	8.7	pH meter instrument (Brower and Zar, 1984)
EC (1:10) dSm^{-1}	4.45	4.48	Electrical conductivity meter (Rowell, 1994)
TN (%)	1.5	1.4	Microkjeldahl method (FAO, 2008).
Soluble N ($NH4^+$) (mg/kg)	861	855	FAO (2008)
Soluble N ($NO3^-$) (mg/kg)	65	63	FAO (2008)
Organic Matter (%)	41.65	41.0	Page *et al.* (1982)
Organic Carbon (%)	24.16	24.11	C content % = O M % ÷ 1.7241 (Nelson and Sommers, 1996)
C/N Ratio	16:1	15:1	C content % / N content %
TP (%)	1.65	1.68	Spectrophotometrically (FAO, 2008)
TK (%)	1.41	1.43	Flame photometry (FAO, 2008)

2.4 Measured data

Growth parameters were measured at the field as shown in Table (5).

2.5 Statistical analysis

The obtained data were analyzed using the statistical package MSTAT-C (Nissen, 1989). Mean values were compared for each other using the Least Significant Differences (LSD) at the probability level of 0.05 where the effects of the treatments were significant at 5% level of probability.

Table (5): Wheat growth parameters and its yield.

Sl. No.	Observations recorded	Periodicity	Methods followed
2.4.1	Yield attributing characters		
	Grain yield	At harvest	After threshing, the grains of each plot were weighed, and the average grain yield (ton/feddan) was calculated at 15.5% moisture.
	Biological yield	At harvest	Weighting all the dry plants at each plot before shelling.
	Straw yield (ton/feddan)	At harvest	By subtracting from biological yield (ton/feddan) the grain weight (ton/feddan) for each plot.
2.4.2	Yield components		
	The average number of grains/spike	At harvest	
	The average weight of 1000- grains (gm)	At harvest	

2.6 DSSAT modeling

2.6.1 Model inputs

The DSSAT model requires daily weather data, including the maximum and minimum daily air temperature, daily precipitation, and solar radiation. Also, it requires soil data including general site, soil surface information and soil profile characteristics (physical, chemical and morphological properties). Also, it requires detailed crop management information including initial soil water content, soil inorganic N, crop cultivar, plant density, sowing date, and fertilization (Hoogenboom *et al*., 2012).

2.6.2 Model calibration

The cultivar coefficients must be calibrated under the normal optimum conditions. So, CERES-Wheat model was calibrated for the grown field that determinate wheat developing using three irrigation regimes and five integrated fertilization programs under Upper Egypt conditions. This calibration was achieved by comparing the input data of the first season, with the simulated values comes out from the model.

2.6.3 Model validation

Observed experimental data of wheat in the second season were used to validate the performance of the CERES-Wheat model.

2.6.4 Model evaluation

Different statistical tools were used to evaluate the performance of the model in predicting various parameters. Relative root mean square error (RRMSE) and coefficient of residual mass (CRM) were used to evaluate the DSSAT model. The CERES-Wheat model was evaluated according to the following statistical parameters.

2.6.4.1 Relative root mean square error

Both the observed and simulated data by studied models were compared using the relative root mean square error (RRMSE) as described by Loague and Green (1991). The simulation is considered excellent with RRMSE<10%, good if 10–20%, fair if 20–30%, poor if >30% (Jamieson *et al*., 1991). This parameter was calculated as follows:

$$RRMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{N}(P_i - O_i)^2} \times \frac{100}{\bar{O}}$$

Where: n is the number of observations, P_i and O_i are predicted and observed values respectively, $\bar{O}$ is the observed mean value.

2.6.4.2 Coefficient of residual mass

The coefficient of residual mass (CRM) was used to measure the tendency of the model to overestimate or underestimate the measured values. The CRM is defined by the following equation:

$$CRM = 100 \times \frac{[\sum O_i - \sum S_i]}{\sum O_i}$$

Where, O_i = observed variable, S_i = simulated variable.

A negative CRM value indicates a tendency of the model towards overestimation (Xevi *et al*., 1996). The simulated data were compared with experimental data and agreement has been checked by CRM and also by the percentage difference between these two values. The permissible or tolerance percentage error is up to 20 percent. If the difference between simulated and observed values is/are above 20 percent than the model performance, it will report as poor and if the difference lies within 20 percent range, it will report good or close agreement.

2.6.4.3 The index of agreement

The index of agreement (d) was estimated as shown in the following equation:

$$d = 1 - \left[\frac{\sum_{i=1}^{n}(S_i - O_b)^2}{\sum_{i=1}^{n}(|S_i| + |O_b|)^2}\right]$$

Where n is the number of observations, S_i the predicted observation, O_b is a measured observation, S_i = S_i − M and Ob = O_b − M (M is the mean of the observed variable). So, if the d-statistic value is closer to one, then there is good agreement between the two variables 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.

3. Results and Discussion

3.1 Wheat yield and its components

3.1.1 Grains number /spike

The grains number /spike showed significant response to irrigation treatments during both seasons as shown in Table (6) and Figure (1). Irrigation scheduling at I1 and I2 significantly increased grains number /spike by 8.3% compared to irrigation scheduling at I3 in the 1st season, also irrigation scheduling at I1 and I2 and significantly increased grains number /spike by 26.3 and 28.5% in the 2nd season, compared to irrigation scheduling at I3, respectively.

Table (6): Wheat yield and its components as affected by irrigation scheduling, and N fertilization regimes in both seasons.

Treatments		No of grains/spike		1000-grains (g)		Grain yield (ton/feddan)		Straw yield (ton/feddan)	
		2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
I1	F1	60	56	43.7	43.5	2.27	1.93	7.13	6.05
	F2	53	58	48.9	48.3	2.74	2.30	7.10	6.37
	F3	55	59	48.9	49.2	3.26	2.40	7.98	6.40
	F4	62	59	49.6	47.5	3.46	2.57	8.03	7.00
	F5	64	50	47.7	47.0	3.32	2.47	9.81	6.50
I2	F1	55	54	43.5	47.1	2.32	1.89	7.10	5.32
	F2	58	50	42.3	44.4	2.77	2.28	7.37	5.67
	F3	60	63	44.2	45.0	3.32	2.37	8.10	6.38
	F4	60	61	50.6	45.0	3.53	2.40	8.73	6.21
	F5	60	58	49.7	45.6	3.32	2.30	8.67	6.84
I3	F1	52	46	43.7	44.7	2.21	1.77	7.13	5.04
	F2	53	43	45.5	43.3	2.59	2.13	7.53	5.25
	F3	53	45	48.6	42.9	2.94	2.27	7.87	6.25
	F4	55	43	45.2	43.8	3.35	2.30	7.93	6.12
	F5	58	46	46.4	43.5	3.21	2.17	8.13	6.08
Average		57	53	46.6	45.4	2.97	2.24	7.91	6.10
LSD (0.05)	I	4.6	8	N.S.	2.47	0.09	0.14	0.31	0.54
	F	N.S.	N.S.	2.71	N.S.	0.17	0.15	0.40	0.43
	IxF	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.69	N.S.

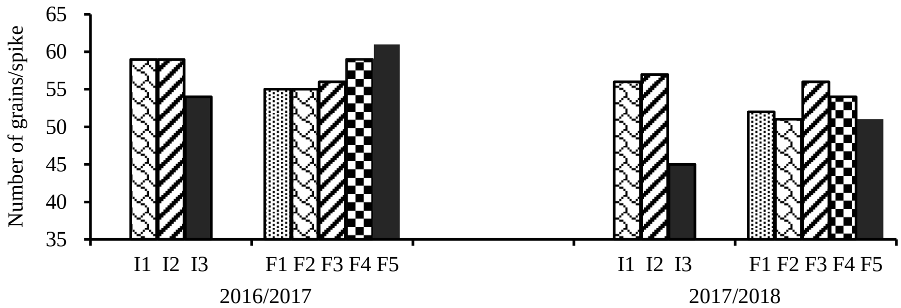

Figure (1): Grains number /spike as affected by irrigation scheduling and N fertilization regimes in 2016/17 and 2017/18 seasons.

These results indicated that the maximum grains number /spike were obtained through irrigation scheduling at 1.2 and 1.0 values of accumulated pan evaporation. This might be attributed to the positive effect of more available moisture. The reproductive growth stage is more sensitive to drought than the vegetative stage, resulting in fewer flowers, poor pod or fruit set, which decreases seed numbers (Pushpavalli *et al.*, 2014), these results are in agreement with those of Youssef *et al.* (2013) and Rao *et al.* (2013). Application of organic and inorganic amendments exerted insignificant variation in wheat grains number /spike during both seasons. The data in figure (5) and table (7) indicated that the use of F5 treatment increased grains number /spike by 9.4, 10.6, 7.7 and 3.0% in the 1st season compared to F1, F2, F3 and F4 treatments, respectively. While F3 treatment increased grains number /spike by 7.6, 10.0, 2.5 and 8.9% in the 2nd season compared to F1, F2, F4 and F5 treatments, respectively. These results are similar to those obtained by Rehman *et al.* (2008).

3.1.2 Weight of 1000-grains (g)

The 1000-grains weight in Table (6) and Figure (2) showed insignificant increase under irrigation scheduling at I1 and I2 by 4.1% and 0.38% in the 1st season, and significant increase by 7.9% and 4.1% in the 2nd season compared to irrigation scheduling at I3, respectively. It is worthy to mention that the maximum 1000-grains weight of the two seasons was obtained through irrigation scheduling at 1.2 values of accumulated pan evaporation.

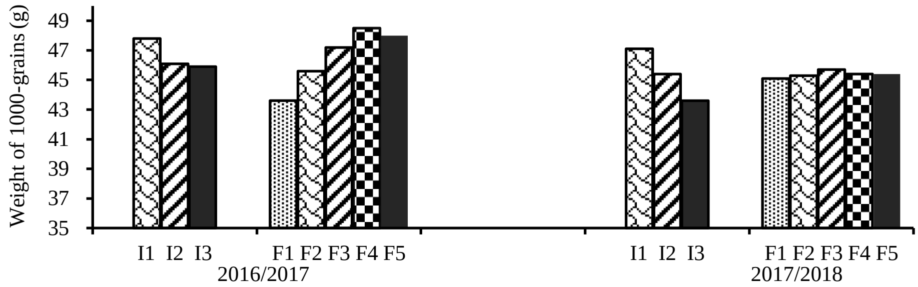

Figure (2): 1000 grains weight as affected by irrigation scheduling and N fertilization regimes in 2016/17 and 2017/18 seasons.

This might be attributed to the positive effect of more available moisture at the grain filling stage on increasing 1000-grain weight (Sehgal *et al.*, 2018). These results are in agreement with those of Namait Allah *et al.* (2008), Rao *et al.*

(2013) and Youssef *et al.* (2013). The use of organic and inorganic amendments together exerted variation in 1000-grains weight as cleared in table (7) and figure (6). Application of F4 treatment led to a significant increase in 1000-grains weight by 11.0, 6.3, 2.6 and %1 in 2016/17 season compared to F1, F2, F3and F5 treatments, respectively. While F3 treatment increased insignificantly the 1000-grains weight by 1.3, 0.79, 0.61 and 0.76% in the 2nd season, compared to F1, F2, F4 and F5 treatments, respectively. The large accumulation of proteins and other reserved food in the seed that caused increases in 1000 grain weight may be due to the nutrients availability especially nitrogen from the applied fertilizers, where N portion released from organic sources and the other from mineral source. The mineral N source fulfills the N requirements at early growth stages while farmyard manure facilitated crop with maximum nutrients in later stages. In combination (mineral + organic) nourished the crop in initial stages as well as in later stages (Shah *et al.*, 2010). These results are in accordance with those of Jala-Abadi *et al.* (2012), Mohamed and Abdel-Rahman (2015), and Ahmed *et al.* (2017).

3.1.3 Grain yield (ton/feddan)

The mean wheat grain yields were 2.97 and 2.24 t fed^{-1} in the 1st and 2nd season, respectively (Table 6 and Figure 3). The yield production in the first season increased by 33% compared to that of the 2nd one. This might be attributed to the cooler weather conditions in the 1st season as it shown in Table (1). The reduction in the productivity in the second season is attributed to higher temperature, which could have negative impacts as heat stress on pollen fertility and grain abortion (Calderini *et al*., 1999). High temperatures also accelerate crop development, and the duration of crop growth phases decreases, producing negative effects on final grain weight and yield in field crops (Sánchez *et al.*, 2013), which resulting in fewer spikelets per spike and grains per spikelet in the second season. Regarding irrigation treatments, the wheat grain yield (ton feddan^{-1}) at I1 and I2 were significantly increased by 5.2 and 6.7% in the 1st season, and by 9.8 and 5.7% in the 2nd season compared to irrigation scheduling at I3, respectively. From the abovementioned results, it could be concluded that maximum grain yield (ton/fed.) values of both seasons were obtained through irrigation scheduling at 1.2 and 1.0 values of accumulated pan evaporation. These results are in agreement with those of El-Marsafawy (2000), Rayan*et al.* (2000) and Rao *et al.* (2013). The integrated fertilization clearly enhanced wheat grain yield since F4 treatment led to a significant increase in wheat grain by 52.1, 27.5, 8.5 and 4.9% in the 1st season, and by 30, 8.4, 3.3 and 4.8% in the 2nd season compared to F1, F2, F3 and F5 treatments, respectively. These results are in harmony with those obtained by Shah and Ahmad (2006), Shah *et al.* (2010) and Gomaa *et al.* (2015). The results indicated that the maximum grain yield of both seasons was obtained through irrigation scheduling at I1 and I2 of accumulated pan evaporation and F4 fertilization regime (75% mineral and 25% organic). This increase is run the same trend of increasing grains number /spike and 1000-grain weight.

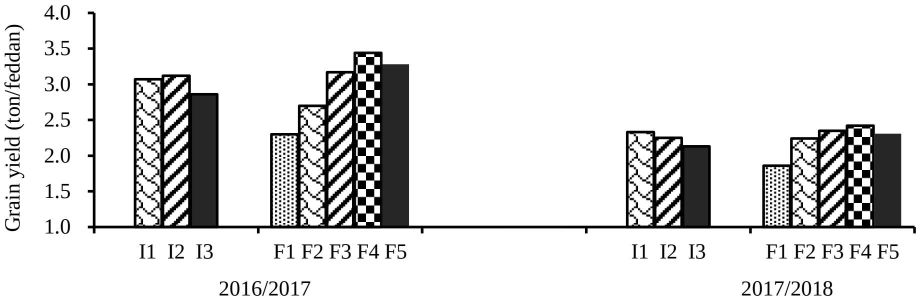

Figure (3): Grain yield (ton/feddan) as affected by irrigation scheduling, and N fertilization regimes in the two studied seasons.

3.1.4 Straw yield (ton/feddan)

The straw yield in Figure (4) and Table (6) showed a was significant increase at I1 and I2 by 3.8 and 3.6% in the 1st season, and by 12.5 and 5.8% in the 2nd season compared to irrigation scheduling at I3, respectively. The results indicated that the maximum straw yield values of both seasons were obtained through irrigation scheduling at 1.2 values of accumulated pan evaporation. This increase could be attributed to plant height and leaf area increases. These results are in agreement with those of Namait Allah *et al.* (2008), El-Sayed (2012), and Youssef *et al.* (2013). Regarding fertilization regimes, F5 treatment led to a significant increase in straw yield by 24.6, 21.0, 11.2and %7.8 in the 1st season and by 18.2, 12.3, 2.0 and 0.48% in the 2nd one compared to F1, F2, F3 and F4 treatments, respectively (table 7 and figure 8). Singh and Agarwal (2001) reported that the application of mineral N alone or with organic N increased plant growth significantly due to the stronger role of N in cell division; cell expansion and enlargement which ultimately affect the vegetative growth of wheat plant particularly plant height. These results are in harmony with Halepyati (2001), and Subhan*et al.* (2017).

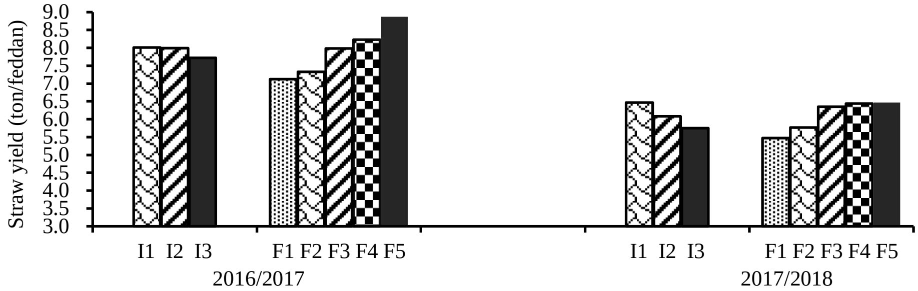

Figure (4): Straw yield (ton/feddan) as affected by irrigation scheduling, and N fertilization regimes in the two studied seasons.

3.2 Wheat modeling

3.2.1 Calibration of the CERES-Wheat model

Wheat growth and yield data of the 2016/17 growing season were used to calibrate the DSSAT model and to determine the genetic coefficients of Misr2 cultivar under Upper Egypt condition. Table (7) showed the definition and the calibrated value of Misr2 wheat cultivar. These genetic coefficients explain how the life cycle of the cultivar responds to its environment.

Table (7): Genetic coefficients for wheat variety Misr 2.

Coefficient	Definition	Minimum	Maximum	Calibrated values
P1V	Days at optimum vernalizing temperature required to complete vernalization.	0	60	1.0
P1D	Percentage reduction in development rate in a photoperiod 10 hour shorter than the threshold relative to that at the threshold	0	200	90
P5	Grain filling (excluding lag) phase duration (˚C.d).	100	999	650
G1	Kernel number per unit canopy weight at anthesis (# g^{-1}).	10	50	45
G2	Standard kernel size under optimum conditions (mg).	10	80	80
G3	Standard, non-stressed dry weight (total, including grain) of a single tiller at maturity (g).	0.5	8	8
PHINT	Interval between successive leaf tip appearances (˚C.d)	30	150	150

The minimum crop parameters required for cultivar coefficients calculations include dates of emergence, anthesis, and physiological maturity, maximum leaf area index, grains number per square meter, grains number per spike, grain and biological yield and harvest index. The default wheat cultivar CI0001 Yecora_Rojo (in WHCER045.CULfile) was selected for cultivar calibration. The calibration was made using a 'Trial and Error' method by setting up a small change (*i.e.*, ±5 %) of each parameter until the desired level of agreement between simulated and observed values was reached. The average of simulated grain yield was 2689 kg/feddan and the observed grain yield average was 2974 kg/feddan (Figure 5). The highest grain yield (3530 kg/feddan) was recorded under 1.0 evaporation pan coefficient and received 75% organic and 25% mineral N (I2F4 treatment), and it was 3413 kg/feddan for the observed or simulated yield. Also, the lowest grain yield was recorded under 0.8 evaporation pan coefficient and received 100% organic N (I3F1 treatment) and it was 2210 kg/feddan and 1688 kg/feddan for observed and simulated yield, respectively.

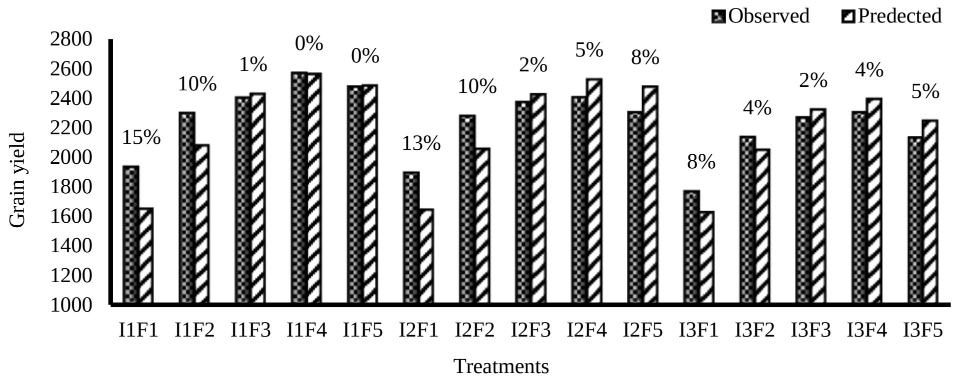

Figure (5): The observed and predicted wheat grain yield in 2016/2017 season.

3.2.2 Validation of CERES-Wheat model

The measured experimental data of wheat in the second season (2017/2018) were used to validate the performance of CERES-Wheat model. The observed and predicted grain yield data in 2017/2018 by CERES-Wheat are presented in Figure (6). The average of simulated grain yield was 2196 kg/feddan, and the observed grain yield average was 2234 kg/feddan. The highest grain yield (2567 kg/feddan) was recorded under 1.2 evaporation pan coefficient and received 75% organic and 25% mineral N (I1F4 treatment), and it was 2560 kg/feddan for observed or simulated yield. While the lowest grain yield (1767 kg/ feddan) was recorded under 0.8 evaporation pan coefficient and received 100% organic N (I3F1 treatment) and it was 1625 kg/ feddan for observed and simulated yield.

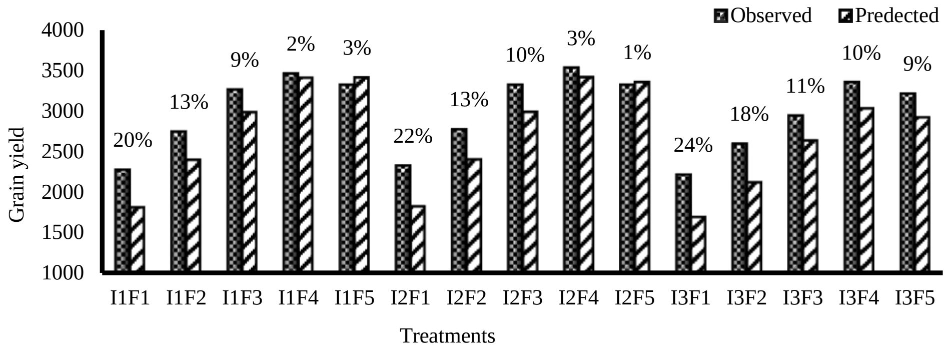

Figure (6): The observed and predicted wheat grain yield in 2017/2018 season.

3.2.3 Evaluating CEARS-Wheat model using data of the first growing season

Predicted and observed wheat grain yield for both seasons, RRMSE, CRM and d-State evaluation among them are presented in Table (8). Generally, DSSAT showed a reasonable ability for wheat grain yield prediction. The RRMSE showed an excellent interaction between predicted and observed data, and its value was 6.6 for grain yield. The coefficient of residual mass (CRM) and the Index of agreement (d) indicated a good agreement for grain yield, and its values was 9.6 and 0.90, respectively. In the second season, DSSAT confirmed the similar coincidence of the first season, RRMSE indicated an excellent agreement, and its value was 4.1 for wheat grain yield. The CRM value appeared to be close agreement; it was 2.6. In the same trend, d-State value was 0.92 for grain yield.

Table (8): The simulated & observed wheat grain yield for both seasons, RMSE, CRM and d-State evaluation coincidence.

Treatment	2016/17 Grain yield (kg/feddan)		2017/18 Grain yield (kg/feddan)	
	Simulated	Observed	Simulated	Observed
I1F1	1806	2270	1649	1933
I1F2	2393	2740	2077	2296
I1F3	2981	3260	2427	2400
I1F4	3402	3460	2560	2567
I1F5	3407	3320	2483	2474
I2F1	1818	2320	1643	1891
I2F2	2397	2770	2054	2277
I2F3	2982	3320	2422	2369
I2F4	3413	3530	2524	2403
I2F5	3353	3320	2475	2301
I3F1	1688	2210	1625	1767
I3F2	2116	2590	2047	2133
I3F3	2631	2940	2320	2267
I3F4	3028	3350	2391	2300
I3F5	2916	3210	2244	2130
RRMSE	6.6		3.9	
CRM	9.6		1.7	
d	0.90		0.92	

The results confirmed that the model was able to predict wheat grain yield under the studied treatments, at Upper Egypt condition. These results were recommended by Choudhury *et al.* (2018) under Bangladesh environment, Kumar *et al.* (2017) under Western Zone of Haryana, and Abou El–Enin *et al.* (2016) who examined CERES-Wheat model under Egypt condition, and they found a very good capability of the model for predicting grain yield at different locations.

4. Conclusion

In this study, after successful calibration and validation of the model, simulated wheat yields (Misr2 cultivar) from DSSAT-Ceres wheat were evaluated with observed wheat yields grown at the two studied seasons, 2016/17 and 2017/18. The model performance was good under different irrigation and nitrogen application management for Upper Egypt condition. Thus, analysis of the impacts of different management and climate change could be applied.

References

Abou El–Enin, M. M., Abo-Remaila, S. I. and Mahmoud, A. S. (2016), "Application and evaluation of DSSAT v.4.6.1 program for simulation of wheat and soybean yields in Egypt", *Journal of Basic and Environmental Sciences*, Vol. 3, pp. 85–97.

Ahmed, B., Ishag, A. A. Hassan, M. K. Ahmed, M. O. (2017), "Response of two wheat cultivars (*Triticum aestivum L*) to amended nitrogen fertilizer on yield and grain quality in Halfa Elgadidah Area", *MOJ Biology and Medicine*, Vol.1 No. 5, pp. 133–136.

Arora, V. and Gajri, R. (1998), "Evaluation of a crop growth-water balance model for analyzing wheat responses to climate and water limited environment", *Field Crops Research*, Vol. 59, pp.213–224.

Brower, J. E. and Zar, J. H. (1984), *Field and laboratory methods for general ecology*, Wm. C. Brown Publishers, Dubuque, Iowa, USA, pp. 226.

Calderini, D. Abeledo, L. Savin, R. and Slafer, G. A. (1999), "Effect of temperature and carpel size during pre-anthesis on potential grain weight in wheat", *The Journal of Agricultural Science*, Vol. 132 No. 04, pp. 453–459.

Chandra, K. (2005), *Production and quality control of organic inputs*, Regional Director, Regional Centre of Organic Farming, Hebbal, Banglaore, India.

Choudhury, A. K. Ishtiaque, S. Sen, R. Jahan, M. A. H. S. Akhter, S. Ahmed, F. Biswas, J. C. Manirruzaman, M. Hossain, M. B. MuinnuddinMiah, M. Rahman, M. M. Zahan, T. Khan, A. S. M. M. R. and Kalra, N. (2018), "Calibration and validation of DSSAT model for simulating wheat yield in Bangladesh", *Haya: The Saudi Journal of Life Sciences*, Vol. 3 No. 4, pp. 356–364.

El-Marsafawy, S. M. (2000), *Scheduling irrigation of wheat crop under different phosphorus fertilizer application times in Middle Egypt*, Proceedings of the 5th Conference on Meteorology & Sustainable Development, pp. 182–195.

El-Sayed, M. M. (2012), Integrating soil moisture with nitrogen management for crop production and environmental protection, Ph.D. Thesis, Faculty of Agriculture, Assiut University, Assiut, Egypt.

FAO. (2005), *Fertilizer use by crop in Egypt*, available at: http://www.fao.org /3/y5863e /y5863e00.htm#Contents.

Farhad, W., Cheema, M. A., Saleem, M. F., Radovich, T., Abbas, F., Hammad, H. M. and Wahid, M. A. (2013), "Yield and quality response of maize hybrids to composted poultry manure at three irrigation levels", *International Journal of Agriculture and Biology*, Vol. 15 No. 2, pp. 181–190.

Feller, C., (1995), *Organic matter in tropical soils with 1:1-type clay, Research of functional organic compartments, A particle-size approach*, Ph.D. Thesis, Travaux University, France.

FAO (1980), *Soil and plant testing as a basis of fertilizer recommendations*, FAO Soils, Bulletin No. 38/2, Rome, Italy.

FAO (2008), *Fertilizer and Plant Nutrition*, Bulleting 19, FAO, Rome, Italy.

Gomaa, M. A. Radwan, F. I. Rehab, I. F. and Mabrouk, W. S. (2015), "Response of bread wheat to organic and nitrogen fertilization", *Middle East Journal of Agriculture Research*, Vol.4 No. 4, pp. 712–716.

Halepyati, A. S. (2001), "Influence of irrigation and nitrogen levels on growth and yield of wheat", *Karnataka Journal of Agricultural Sciences*, Vol. 14 No. 2, pp. 449–450.

Hoogenboom, G., Jones, J. W., Wilkens, P. W., Porter, C. H., Batchelor, W. D., Hunt, L. A., Boote, K. J., Singh, U., Uryasev, O., Bowen, W. T., Gijsman, A., du Toit, A., White, J. W., and Tsuji, G. Y. (2004), *Decision support system for agrotechnology transfer Version 4.0. [CD-ROM]*, University of Hawaii, Honolulu, Hawaii, USA.

Hoogenboom, G., Jones, J. W., Wilkens, P. W., BootePorter, C. H., Hunt, L. A., (2012), *Decision Support System for Agro technology Transfer (DSSAT) Version 4.5.*, University of Hawaii, Honolulu, Hawaii, USA.

Jala-Abadi, A. L., Siadat, S. A., Bakhsandeh, A. M., Fathi, G. and Saied, K. H. A. (2012), "Effect oforganic and inorganic fertilizers on yield and yield components in wheat (*T. aestivum and T. durum*) genotypes", *Advances in Environmental Biology*, Vol. 6 No. 2, pp. 756–762.

Jamieson, P. D., Porter, J. R. and Wilson, D. R. (1991), "A test of the computer simulation model ARC-WHEAT on wheat crops grown in New Zealand", *Field Crops Research*, Vol. 27, pp 337–350.

Jones, J. W., Hoogenboom, G., Porter, C. H., Boote, K. J., Batchelor, W. D., Hunt, L. A., Wilkens P. W, Singh U Gijsman, A. J., Ritchie J. T. (2003), "The DSSAT cropping system model", *European Journal of Agronomy*, Vol. 18 No. 3–4, pp. 235–265,

Jones, M. R. (2013), *Incorporating the canegro sugarcane model into the DSSAT v4 cropping system model framework*, M.Sc. Thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Khalil, F. A., H. Farag, G. El-Afandi, and Ouda, S. A. (2009), *Vulnerability and adaptation of wheat to climate change in Middle Egypt*, Proceeding of the 13th International Conference on Water Technology, Egypt, pp. 12–15.

Koushal, S., Sharma, A. K. and Singh, A. (2011), "Yield performance, economics and soil fertility through direct and residual effects of organic and inorganic sources of nitrogen as substitute to chemical fertilizer in rice-wheat cropping system", *Research Journal of Agricultural Sciences*, Vol. 43 No. 3, pp. 762–774.

Kumar, M., Pannu, R. K., Singh, R. J., Singh, B., Dhaka A. K. and Rajeev (2017), "Prediction of growth and yield of late sown Wheat Using DSSAT (v4.5) model under Western Zone of Haryana", *International Journal of Current Microbiology and Applied Sciences*, Vol. 6 No. 3, pp. 1687–1696.

Loague, K. and Green, R. E. (1991), "Statistical and graphical methods for evaluating solute transport models: Overview and application", *Journal of Contaminant Hydrology*, Vol. 7, pp. 51–73.

Mohamed, K. A. and Abdel-Rahman, M. A. M. (2015), "Effect of different sources of nitrogen fertilizers combined with vermiculite on productivity of wheat and availability of nitrogen in sandy soil in Egypt", *American Journal of Plant Nutrition and Fertilization Technology*, Vol. 5, pp. 50–60.

Namait Allah, Y. O., Sadik, M. K., Abd El-Haleem, A. M. A., Eid, H. M. and Salem, H. M. (2008), "Effect of irrigation scheduling and applied nitrogen level on water relation, yield and yield components for wheat crop grown in Middle Egypt (Giza region)", *Journal of Biological Chemistry and Environmental Science*, Vol. 3 No. 4, pp. 81–102.

Nelson, D. W. and Sommers, L. E. (1996), "Total carbon, organic carbon, and organic matter", In: *Methods of soil analysis*, Part 2, 2nd ed., Page, A. L. *et al*. (eds.), American Society of Agronomy Inc., Madison, USA, pp. 961–1010.

Nissen, O. (1989), *MSTAT-C: A micro-computer program for the design, management and analysis of agronomic research experiments*, Michigan State University, East Lansing, Michigan, USA.

Noreen, F., Noreen, S. (2012), "Effect of different fertilizers on yield of wheat", *International Journal of Science and Research (IJSR)*, Vol. 3 No. 11, pp. 1596–1599.

Page, A. L., Miller, R. H. and Keeny, D. R. (1982), *Methods of Soil Analysis*, Part 2, Soil Science Society of America Inc., Madison, Wisconsin, USA.

Piper, C. S. (1966), *Soil and plant analysis*, Hans Publishers, Bombay, India.

Pushpavalli, R., Zaman-Allah, M., Turner, N. C., Baddam, R., Rao, M. V. and Vadezm, V. (2014), "Higher flower and seed number leads to higher yield underwater stress conditions imposed during reproduction in chickpea", *Functional Plant Biology*, Vol 42, pp 162–174.

Rao, S. S., Regar, P. L., Tanwar, S. P. S. and Singh, Y. V. (2013), "Wheat yield response to line source sprinkler irrigation and soil management practices on medium-textured shallow soils of arid environment", *Irrigation Science*, Vol. 31 No. 11, pp. 85–97.

Rayan, A. A., El-Marsafawy, S. M., Ainer, N. G. and Soliman, S. E. (2000), "Schedule irrigation of wheat crop in Upper Egypt under some sowing dates", *Egyptian Journal of Applied Sciences*, Vol. 15 No. 1, pp. 10–23.

Rehman, S., Khalil, S. K., Rehman, A. and Saljoqi, A. U. R. (2008), "Organic and inorganic fertilizers increase wheat yield components and biomass under rainfed condition", *Sarhad Journal of Agriculture*, Vol. 24 No. 1, pp. 12–18.

Rowell, D. L. (1994), *Soil science: method and applications*, Longman publishers, Singapore, pp. 350.

Sánchez, B., Rasmussen, A. and Porter, J. R. (2013), "Temperatures and the growth and development of maize and rice: A Review", *Global Change Biology*, Vol. 20, pp. 408–417.

Sehgal, A., Sita, K., Siddique, K. H., Kumar, R., Bhogireddy, S., Varshney, R. K., Hanumantharao, B., Nair, R. M., Prasad, P. V. and Nayyar, H. (2018), "Drought or/and heat-stress effects on seed filling in food crops: Impacts on functional biochemistry, seed yields, and nutritional quality", *Frontiers in*

Plant Science, Vol. 9 Article ID: 1705.

Sestak, C. B., Catsky, J. and Jarris, P. G. (1971), "Plant Synthesis", In *Production Manual of Methods*, Dr. W. Junk Publishers, The Hague, Netherlands, pp. 343–381.

Shah, Z. and Ahmad, M. I. (2006), "Effect of integrated use of farm yard manure and urea on yield and nitrogen uptake of wheat", *Journal of Agricultural and Biological Science*, Vol.1, No.1, pp. 60–65.

Shah, A. S., Shah, S. M., Mohammad, W., Shafi, M., Nawaz, H., Shehzadi, S. and Amir, M. (2010), "Effect of integrated use of organic and inorganic nitrogen sources on wheat yield", *Sarhad Journal of Agriculture*, Vol. 26 No. 4, pp. 559–563

Singh, R. and Agarwal, S. K. (2001), "Growth and yield of wheat (*Triticum aestivum* L.) as influenced by levels of farmyard manure and nitrogen", *Indian Journal of Agronomy*, Vol. 46 No. 3, pp. 462–467.

Smajstrla, A. G., Zazueta, F. S., Clark, G. and Pitts, D. J. (2000), *Irrigation scheduling with evaporation pans*, Vol. 254, Extension Bulletin, Institute of Food and Agricultural Sciences, University of Florida Extension, USA, pp. 11.

Stanhill, G. (2002), "Is the Class A evaporation pan still the most practical and accurate meteorological method for determining irrigation water requirements", *Agricultural and Forest Meteorology*, Vol. 112 No. 3–4, pp. 233–236.

Subhan, Q. U. K., Mansoor, M. and Khan, M. J. (2017), "Effect of organic and inorganic fertilizer on the water use efficiency and yield attributes of wheat under heavy textured soil", *Sarhad Journal of Agriculture*, Vol. 33 No. 4, pp. 582–590.

Xevi, E. L., Gilley, J. and Feyen, J. (1996), "Comparative study of two crop yield simulation models", *Agricultural Water Management*, Vol. 30, pp. 155–173.

Youssef, M. A., El-Sayed, M. M. and Sadek, I. (2013), "Impact of organic manure, bio-fertilizer and irrigation intervals on wheat growth and grain yield", *American-Eurasian Journal of Agricultural & Environmental Sciences*, Vol. 13 No. 11, pp. 1488–1496.

Zia, M. S., Mann, R. A., Aslam, M., Khan, M. A. and Hussain, F. (2000), *The role of green manuring in sustaining rice-wheat production*, In: Proceedings of Symposium on Integrated Plant Nutrition Management, NDFC, Islamabad, Pakistan, pp. 130–149.