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Calibration and Validation of DSSAT V.4.6.1, CERES and CROPGRO-Models for Simulating No-Tillage in Central Delta, Egypt

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Abstract

Crop simulation programs allow analyzing and exploring various tillage-rotation combinations and management. This study was conducted to apply and evaluate the DSSAT program under Egyptian conditions. The study was carried out to investigate the effect of tillage system, fertilizer rates and cereal/legume rotation on the crop yield and soil quality. The CERES-maize and CROPGRO-broad bean models were used to simulate the studied crop yield.

Field observations showed that, the effect of tillage systems during the summer season of 2013 did not differ significantly due to studied maize traits. Regarding, winter season of 2013/2014), the results showed that, CA tillage system increased significantly all studied broad bean traits as compared with the other tillage systems. Referring to, the summer season of 2014, CA system scored the significant high values for the studied maize traits.

As for the effect of studied NPK fertilizer levels, results indicated that, 100% of the recommended doses of NPK favored the values of the studied maize and broad bean traits significantly during summer 2013 and winter 2013/2014, as compared by 50% of the recommended dose of NPK fertilizers, while, there are no-significant difference between the two fertilizer levels for maize traits in the third season (summer, 2014).

With regard to, the first order interaction effect between the tested factors, results of the three trial seasons revealed that, growing maize or broad bean under the condition of conservation agriculture (CA) and fed by 100% or 50% of the recommended dose of NPK fertilizers scored the greatest values for most of maize studied traits and broad bean, and the differences between them did not reach the significant level. On contrast, the lowest value were resulted under the condition of Conventional agriculture (CT) and fed by the 50% of the recommended dose of NPK fertilizers.

The models that were used in this study also reflected this trend. The CERES-maize and CROPGRO-broad bean models greatly discovered stimulation for grain yield/fed., harvest index as affected by interaction effect between tillage systems and fertilizer rats, which their RMSE ranged between excellent and good, RMSE = (8.44, 12.19) and (11.70,16.79) and (0.15, 12.02) for summer 2013, winter 2013/2014 and summer 2014 seasons respectively, through (maize→ broad bean→ maize) crop sequence.

Keywords: Conservation agriculture; DSSAT v.4.5; NPK fertilizer; Crop sequence

Introduction

Heavy and continuous conventional agriculture can cause loss of soil organic carbon, as well as increase soil erosion and deterioration of soil structure [1]. In the last few years, the search for practices that improve soil fertility and productivity and agricultural sustainability has increased. Interest in conservation agriculture technique (such as reduce and no-tillage) is growing be. Because these practices reduce soil erosion, therefore preserving soil structure and fertility [2]. Improve in the soil structure and increase its productivity by applying conservation agriculture technique has been reported in numerous studies [3]. In 1973/74 Conservation agriculture, synonymous of zero tillage, was used only on 2.8 million ha worldwide. In 1999 zero tillage was adopted on about 45 million ha worldwide, growing to 72 million ha in 2003, and to 154.81 million ha by 2014 [4]. Fastest adoption rates have been experienced in South America where some countries are using no-tillage on about 70% of the total cultivated area.

Many countries talk the direction for applying the conservation agriculture. Conservation Agriculture emerged as new agricultural technique successfully applied over the last years mainly in American countries. However, African agricultural systems have triggered a controversy on CA adoption and its suitability in smallholders' environments. Assessment of CA adoption requires a detailed revision of several social and economic factors and conditions. Figure 1 shows CA adoption in selected countries of Africa.

The crop simulation program such as DSSAT V.4.6.1 could be used to evaluate different tillage practices and crop rotation [5]. This program includes tillage routines that modify soil structure and mix soil constituents. It combines several crop simulation models, soil carbon and nitrogen (N) models, daily soil water model, and field management options to simulate crop productivity and environmental effects. The DSSAT V.4.6.1includes CERES-based Soil organic matter model and CENTURY model [1,6,7].

Our objective of this study was to evaluate the capacity of DSSATv.4.6.1-CERES and CROPGRO models to predict yield and its components traits of some Egyptian maize and broad bean varieties

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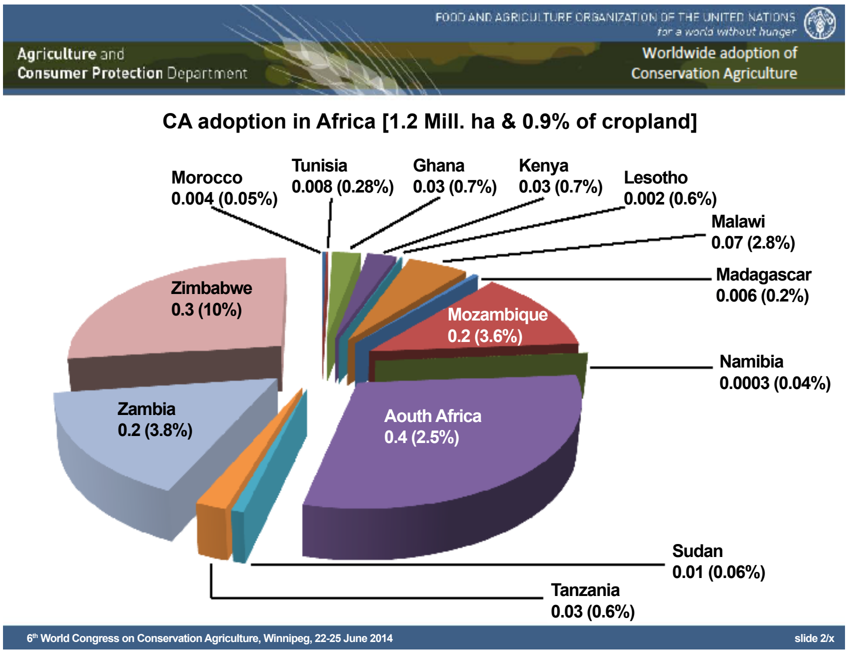

Figure 1: Shows CA adoption in selected countries of Africa.

grown in clay soil under different tillage systems as well as fertilizer rats through cropping system of (maize→ broad bean→ maize).

Materials and Methods

The materials and methods of this investigation are presented as follows:-

Field experiment

The field experiment started in summer 2013 and continued for 3 seasons in Gemmieza agricultural experimental research station, Egyptian Agricultural Research Center (ARC).

The studied experimental treatments:

***Tillage systems treatments (TS)*:**

• *Conventional agriculture (CT)*

In this system, the normal conventional agricultural practises of growing crop were done such as tillage.

• *Conservation agriculture (CA)*

Under the conditions of this system, the soil was left without any land preparation and the previous crop residuals was hammered and left on soil surface and the seed was growing by hand drilled around hills.

• *Semi-conservation agriculture (SCA)*

This method as the same conservation agriculture method without hand drilled around hills.

Fertilizer treatments:

• the recommended fertilizer (NPK)

• half of the recommended fertilizer (1/2 NPK)

The phosphorus and potassium fertilizer rate of each crop were applied as, single calcium super phosphate (15.5% P2o5) and potassium sulphate (48% K_2O) during soil preparation for (CT) tillage treatments while that fertilizers were added broadcasting through (SCA) and (CA) tillage systems.

Regarding to, nitrogen fertilizer rate for each crop as shown before in Table 1 was applied in the form of urea (46%N) before water irrigation as follow:

• *Maize crop:*

The total amount was devoted in to two equal portions as follow:

1. Before the first irrigation at plant ages of 20 days from sowing date

2. Before the second irrigation at plant age of 35 days from sowing date.

In reference to, broad bean success inoculation for its seed were done by *R. leguminosarum* bacteria respectively and the nitrogen fertilization take place after 10 days from sowing date at the rate of 15 kg N /fed.

Single hybrid-10 maize, it was sown at the recommended seeding rate (15 kg/fed), in hills, 2-3 grains were hand affair planted in each hill spaced at 20 cm apart, on the 5 and 7th April in 2013 and 2014 seasons respectively and harvested on 16 and 20th August 2013 and 2014 respectively.

As for, Broad bean seeds were planted by affair method by hand at the rate of 2-3 seeds/hill spaced at 20 cm apart. Sowing date on the 22th October 2013/2014 seasons, and harvested on 26th March 2014.

Experimental design

In the three studied seasons, each field experiment included six treatments, which were the combination of three systems of tillage practice, and two levels of NPK fertilizer, the treatments were arranged in a split- plot design with three replicates. The main plots were

Fertilizer crops	Crop variety	Nitrogen (kg N/fad)	$P_2O_{5\ 15\%}$ (kg/fad) Before planting	K_2SO_4 (kg/fad)	Seeding rate (kg/fad)
Broad bean	Egypt-1	15	150	50	60
Corn/maize	Single hybrid-10	120	200	50	15

Table 1: Shows the recommended nitrogen, phosphorous, potassium fertilizer rates, and seeding rates for the studied crops variety.

randomly devoted to the tillage treatments, regarding to, the sub-plots were randomly devoted to the fertilizer rates. 1 m alleys separated these plots from each other.

All plots were irrigated by surface irrigation system every 10 day for maize crop and 20 days intervals for broad bean crop according to region conditions.

Statistical analysis: All data were exposed to the proper statistical analysis according to Gomez [8]. The mean values were compared at 5% level of significance using least significant differences (L.S.D) test.

Studied attributes

Corn /maize crop

Five plant samples were taken randomly from each plot to measure the following traits:

• Cone length (cm).

• Weight of Cone (g).

• Biological yield (kg/fed): whole plants of each plot were harvested then weighted and transformed to biological yield per fed. According the plot area.

• Grain yield (kg/fed) It was determined by weighting the total grain yield of each plot, then converted to kg/fed.

• Harvest index (HI) was calculated according to the following formula:

HI = Seed yield (kg/fed.)/ Total biological yield (kg/fed.).

Broad bean, Lentil and Maize crops

Ten plants samples were taken randomly from each plot to measure the following traits:

• Number of pods/plant

• Biological yield (kg/fed): whole plants of each plot were harvested then weighted and transformed to biological yield per fed according the plot area

• Seed yield (kg/fed) It was determined by weighting the total seed yield of each plot, then converted to kg/fed.

• 100-Seeds weight (g) was obtained from the weight of 100 seed taken at random sample from each plot.

Crop simulation methods

Model description: The crop simulation model DSSAT (Decision Support System for Agro Technology) was chosen because it has been successfully used worldwide in a broad range of conditions and for multipurpose: as an aid to crop management. More than 18 different crops simulated with CSM, including maize, wheat, rice, barley, sorghum, millet, maize, peanut, dry bean, chickpea, cowpea, faba bean, velvet bean, potato, tomato, bell pepper, cabbage, Bahia and brachiaria and bare fallow. We used DSSAT version 4.6.1 which includes the new tillage model based on the improved CROPGRO and CERES-Till [9]. A model used to predict the influence of crop residue cover and tillage on soil surface properties and plant development. CROPGRO and CERES-Till has been tested for broad bean and maize and has demonstrated the ability to simulate differences in soil properties and broad bean, maize yield under several tillage systems.

Input files for both of CERES-maize model and CROPGRO module requires an experimental details file, a weather data file, a soil data file and a genotype data file.

Experimental details file: Such as: field characteristics, soil analysis data, initial soil water, irrigation and water management, fertilizer management, tillage operations, environmental modifications, harvest management and simulation controls. Details of irrigation events for all the experiments.

Weather data file: The model requires daily weather data for the duration of the growing season. The minimum data required for above two models are solar radiation, minimum and maximum air temperature and rainfall [10].

Soil data file: The data related to soil profile, soil water, soil nitrogen and root growth characteristics, soil taxonomic classification, soil texture and other descriptive data of the experimental site were used to develop the soil file for the experimental station.

Genotype data file: Farmers can change cultivars in order to maximize yield. The DSSAT crop models also have the ability to take that source of variability into account. For each model, the cultivars are characterized by a specific set of genetic coefficients. These coefficients express the genetic potential of each genotype independently of all environmental constraints: soil; weather, etc. by simulating the yield of different cultivars in different conditions, it is possible to select the one (s) that best explore the available resources.

Calibration of models: Model calibration or parameterization is the adjustment of parameters so that simulated values compare well with observed ones. Genetic coefficients of CERES- maize and CROPGRO model are related to photoperiod sensitivity, duration of grain filling, conversion of mass to grain number, grain-filling rates, Maximum weight per seed (g), Time between first flowers and first pod, vernalization requirement, stem size and cold harden. The genetic coefficients used in two models characterize the growth and development of crop varieties differing in maturity as following Table 2 and 3.

Crop model validation: The comparison between actual data and predicted data were done through CERES-wheat, maize and CROPGRO-maize, faba bean, lentil models under DSSAT interface in three steps, i.e. retrieval data (converting data to CERES and CROPGRO model), validation data (comparing between predicted and observed data) and run the model.

Evaluation of applying CERES and CROPGRO model: The two models were evaluated through three methods:

• The normalized root mean square error (RMSE) that is expressed in percent, calculated as explained by Loague [11]. with the help of following Equation: $RMSE=\sqrt{\frac{\sum_{i=1}^{n}(P_i-O_i)^2}{n}\times\frac{100}{M}}$

Where n is the number of observations, Pi and Oi are predicted and observed values respectively, M is the observed mean value. The

Coefficients	Definition	Cultivar
		Single Cross - 10
P1	Thermal time from seedling emergence to the end of the juvenile phase (expressed in degree days above a base temperature of 8°C) during which the plant is not responsive to changes in photoperiod.	190
P2	Extent to which development (expressed as days) is delayed for each hour increase in photoperiod above the longest photoperiod at which development proceeds at a maximum rate (which is considered to be 12.5 hours).	1
P5	Thermal time from silking to physiological maturity (expressed in degree days above a base temperature of 8°C).	1000
G2	Maximum possible number of kernels per plant.	850
G3	Kernel filling rate during the linear grain filling stage and under optimum conditions (mg/day).	7
PHINT	Phylochron interval; the interval in thermal time (degree days) between successive leaf tip appearances.	49

Table 2: Genetic coefficients used in CSM-CERES-model characterize the growth and development of maize variety after Model calibration and validation.

Coefficients	Definition	Cultivar	
		Giza-111	Egypt-1
EM-FL	Time between plant emergence and flower appearance (R) photo thermal days	16.25	18.00
FL-SH	Time between first flower and first pod (R3) (photo thermal days)	10.00	10.90
FL-SD	Time between first flower and first seed (R5) (photo thermal days)	14.00	24.00
SD-PM	Time between first seed (R5) and physiological maturity (R7) photo thermal days	33.35	34.50
FL-LF	Time between first flower (R1) and end of leaf expansion photo thermal days	18.00	45.00
LFMAX	Maximum leaf photosynthesis rate at 30 C, 350 vpm CO2, and high light mg CO2/m2	1.05	1.00
SLAVR	Specific leaf area of cultivar under standard growth conditions cm2/g	350.00	285.0
SIZLF	Maximum size of full leaf (three leaflets) (cm2)	185.00	110.00
XFRT	Maximum fraction of daily growth that is partitioned to seed + shell	1.00	1.00
WTPSD	Maximum weight per seed (g)	0.176	1.10
SFDUR	Seed filling duration for pod cohort at standard growth conditions photo thermal days	42.50	21.00
SDPDV	Average seed per pod under standard growing conditions (#/pod)	2.07	2.40
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photo thermal days)	10.00	18.00
THRSH	The maximum ratio of (seed/ (seed+ shell)) at maturity	78.00	77.00
SDPRO	Fraction protein in seeds (g (protein)/g (seed))	0.40	0.315

Table 3: Genetic coefficients used in CROPGRO-model characterize the growth and development of maize, broad bean and lentil varieties, which were obtained from Model calibration.

simulation is considered excellent with RMSE<10%, good if 10–20%, fair if 20–30%, and poor >30% for yield and yield components, the mean square error (MSE) was calculated into a systematic (MSEs).

- The Index of agreement (*d*) as described by Wilmott et al. [4] 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 is the number of observations, Pi the predicted observation, Oi is a measured observation, P'i = Pi −M and O'i = Oi −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.

The correlation coefficient between observed and predicted data was calculated to show the trend in observed and predicted data. Correlation coefficient: the measure of liner relationship between two variables x and y.

Characteristics studied by CERES and CROPGRO models: At the end of that study, comparison study between the observed and predicted data for the seed or grain yield (Kg/ha) and the harvest index of each studied crop according to the crop simulation program of DSSAT V.4.6.1 program (CERES-Cereal model and CROPGRO-Legumes model) because that traits is the best parameter to observe about the treatment crop effort done under the condition of thread heeds of conservation agriculture triangle (No tillage, permanent soil cover with crop residuals and crop rotations with different plant species).

Results

Maize after broad bean (summer 2013)

Results presented in Table 4 show the effect of tillage systems, NPK fertilizer levels as well as the interaction between them on studied traits of maize during summer 2013 season through (maize→ broad bean→ maize) crop sequence. It is worthy to mention that, insignificant differences had been achieved between Conventional agriculture (CT), semi-conservation agriculture (SCA) and conservation agriculture (CA) for the studied maize traits Figure 2.

Referring to, fertilizer levels, results in the same previous Table 5 indicated that, the recommended doses of NPK significantly favored maize cone length (cm), cone weight (cm), biological yield/fed and grain yield/fed as compared by 1/2 dose of recommended NPK fertilizers by 28.84%, 10.98%, 30.37% and 27.35% respectively. On the other side, the results indicated that, the 1/2 recommended doses of NPK significantly favored maize harvest index as compared by the recommended doses of it by 2.34%.

Concerning to the interaction between studied treatments, results recorded in the same previous Table cleared that, the application of conservation agriculture (CA) and fed by the recommended dose of NPK or half recommended dose of NPK fertilizers scored the greatest value for all maize traits as compared with the other treatments. On

Treatments		Cone length (cm)	Cone weight (g)	Biological yield (kg/fad)	Grain yield (kg/fad)	Harvest index
Tillage systems	**Fertilizer level**					
Conventional agriculture (CT)	**100% NPK**	25.00	391.70	12959.10	4975.00	0.384
	50% NPK	18.33	350.33	9956.00	3918.00	0.394
	Mean	**21.67**	**371.00**	**11457.60**	**4446.50**	**0.389**
Semi-conservation agriculture (SCA)	**100% NPK**	25.33	388.33	12724.30	4842.67	0.381
	50% NPK	20.33	345.00	9761.79	3783.33	0.388
	Mean	**22.83**	**366.67**	**11243.00**	**4313.00**	**0.384**
Conservation agriculture (CA)	**100% NPK**	25.67	392.00	13061.30	5042.67	0.386
	50% NPK	20.33	360.67	10000.40	3966.67	0.397
	Mean	**23.00**	**376.34**	**11530.90**	**4504.67**	**0.391**
	General Mean TS	**22.50**	**371.33**	**11410.50**	**4421.39**	**0.392**
	Mean of NPK					
	100% NPK	**25.33**	**390.67**	**12914.90**	**4953.44**	**0.384**
	50% NPK	**19.66**	**352.00**	**9906.07**	**3889.33**	**0.393**
LSD at 5%						
Tillage systems (TS) =		**NS**	**NS**	**NS**	**NS**	**NS**
Fertilizer (F) =		**3.93**	**28.80**	**377.05**	**139.01**	**0.013**
TS x F =		**7.11**	**39.34**	**776.80**	**286.39**	**0.027**

Table 4: Effect of tillage system and fertilizer levels as well as the interaction between them on yield and yield component of maize through cropping system of (maize→ brad bean→ maize) in season, 2013.

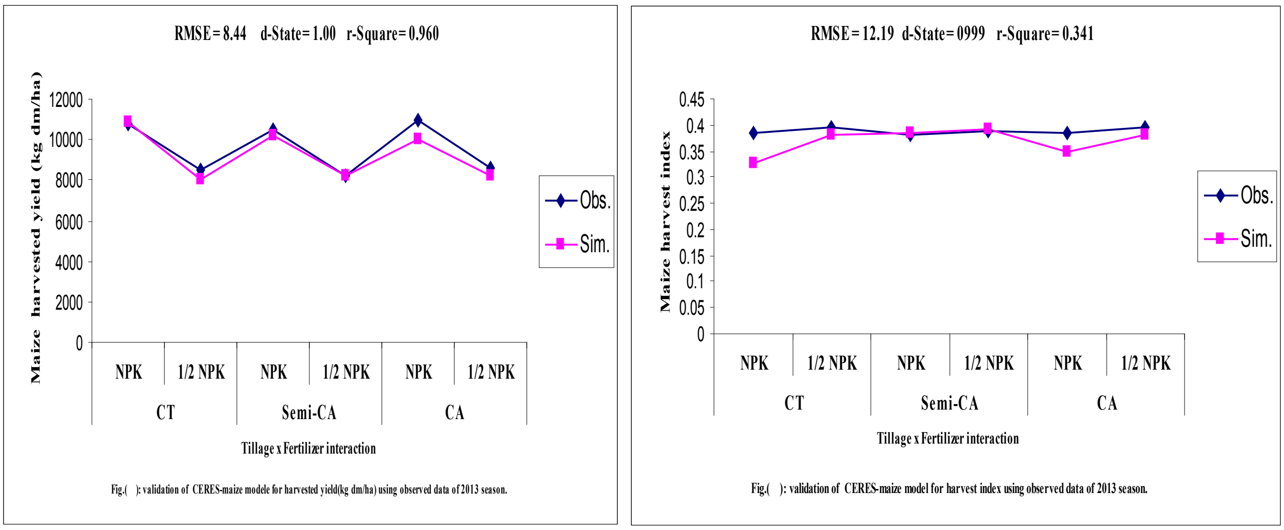

Figure 2: The coincided between observed and predicted data of harvested yield (kg dm/ha) and harvest index of maize as affected by tillage system and fertilizer levels through (maize-broad bean-maize).

Crop sequence		Maize after broad bean (Summer,2013)			
		Grain yield (kg dm/ha)		Harvest index	
Treatments		Observed	Simulated	Observed	Simulated
CT	NPK	10775	10820	0.384	0.328
	1/2 NPK	8486	8014	0.394	0.380
Semi-CA	NPK	10488	10212	0.381	0.385
	1/2 NPK	8194	8220	0.388	0.391
CA	NPK	10921	10000	0.386	0.350
	1/2 NPK	8591	8210	0.397	0.380
Validation CERES-Model					
RMSE=		8.44		12.19	
d-State=		1.000		0.999	
r -Square		0.960		0.341	
Coincided degree		Excellent		Good	

Table 5: The coincided between observed and predicted data of seed yield (kg dm/ha) and harvest index of maize as affected by tillage system and fertilizer levels through (maize-broad bean-maize) crop sequences.

Treatments		No. of pods/plant	Biological yield (kg/fad)	Seed yield (kg/fad)	100- seed Weight(g)
Tillage systems	**Fertilizer level**				
Conventional agriculture (CT)	**100% NPK**	18.00	4623	1182	73.28
	50% NPK	12.67	2693	1062	72.72
	Mean	**15.33**	**3658**	**1122**	**73.00**
Semi-conservation agriculture (SCA)	**100% NPK**	19.67	4783	1194	74.73
	50% NPK	18.00	4737	1172	74.61
	Mean	18.83	**4760**	**1183**	**75.00**
Conservation agriculture (CA)	**100% NPK**	30.00	7290	1517	91.6
	50% NPK	28.67	6137	1403	88.24
	Mean	**29.33**	**6714**	**1460**	**90.00**
	General Mean TS	**21.17**	**5044**	**1255**	**79.2**
	Mean of NPK				
	100% NPK	**22.56**	**5566**	**1298**	**79.87**
	50% NPK	**19.78**	**4522**	**1212**	**78.52**
LSD at 5%					
Tillage systems (TS) =		**0.46**	**110**	**49**	**2.66**
Fertilizer (F) =		**2.13**	**263**	**NS**	**NS**
TS x F =		**8.63**	**543**	**388**	**14.33**

Table 6: Effect of tillage system and fertilizer levels as well as the interaction between them on yield and yield component of broad bean through cropping system of (maize → broad bean→ maize) in season, 2013/2014.

contrast, the lowest values for maize cone length (cm), was resulted under the condition of Conventional agriculture (CT) and fed by the half-recommended dose of NPK fertilizers (18.33 cm). On the other hand, the lowest values for maize cone weight (cm), biological yield/fed and grain yield/fed were resulted under the condition of semi-conservation agriculture (SCA) and fed by the half recommended dose of NPK fertilizers (345 g), (9761.79 kg/fad), (2819.00 kg/fad) respectively.

Validation data by CERES-maize model (predicted data): The values of (RMSE), (D-state) and (r-Square) parameter, which used to make a judgment of the coinciding degree, between observed and predicted data of maize traits as affected by the interaction effect between tillage and fertilizer treatments, showed different levels of the coinciding degree grain yield (kg/ha) and harvest index in summer 2013 season, showed excellent and good compliance (RMSE =8.44 and 12.19), D-state were (1.00 and 0.999) and (r-Square = 0.960 and 0.341) between the observed and predicted data as affected by the previous interaction.

Broad bean after maize (2013/2014)

As shown in the Table 6, shows that broad bean no. of pods/plant, biological yield/fed, seed yield/fed) and 100-seed weight (g) as affected by tillage systems, fertilizer level and the interaction effect between them through (maize→ brad bean→ maize) crop sequence in winter 2013/2014 season. As a matter of fact, results revealed that, conservation agriculture (CA) significantly pronounced its superiority reflected on increase broad bean no. of pods/plant by 91.32%, biological yield/fed by 83.52%, seed yield/fed by 30.16% and 100-seed weight (g) by 23.17% as compare by Conventional agriculture (CT) system.

In relation to, fertilizer levels, results in the previous Table showed that, the recommended doses of NPK significantly favored broad bean no. of pods/plant and biological yield/fed as compared by 1/2 dose of recommended NPK fertilizers by 14.05% and 23.07% respectively. On the opposite of, there are no significant effect between the recommended doses of NPK and 1/2 recommended doses of it for seed yield/fed) and 100-seed weight (g).

In reference to, the interaction effect between studied treatments, results indicated that, cultivating broad bean under the condition of conservation agriculture (CA) and fed by the recommended dose or half dose of NPK fertilizers scored the greatest value for no. of pods/plant (30, 28.67), biological yield/fed (7290, 6137 kg), seed yield/fed (1517, 1403 kg) and 100-seed weight (91.60, 88.24g) and the differences between them not reach to the significant level.

On the contrary, the lowest value for above mentioned traits was resulted under the condition of Conventional agriculture (CT) and fed by the half recommended dose of NPK fertilizers (12.67), (2693 kg/fad.), (1062 kg/fad) and (72.72 g) respectively.

Validation data by CROPGRO-faba bean model(winter 2013/2014 season): Results recorded in the Table 7 and Figure 3 show that, validation indexes which used to measure the simulation accuracy for faba bean characters ranged between good simulation accuracy for both of seed yield (kg/ha) and harvest index (RMSE=11.70 and 16.79), D-state =0.999 and 0.999. As for r-Square was 0.974 and 0.926 respectively.

This trend is in harmony with previous results reported by Hassanein MK [12] who studied faba bean yield and growth predictability using CROPGRO-legume model. It could be concluded that CROPGRO legume model could be used to predict yield and growth of faba bean under Egyptian conditions. In addition to, Oliveira et al. [13] who evaluates the CROPGRO-Dry bean model for simulating dry bean yield. The results show that the crop model can correctly reproduce the observed yield. This finding may indicate that the model is a useful tool to evaluate the crop response to variability and changing climate.

Maize after broad bean (summer 2014)

Results presented in Table 8 described, maize cone length (cm), cone weight (g), biological yield (kg/fad), grain yield (kg/fad) and harvest index as affected by tillage systems, fertilizer level and the interaction effect between them through (maize→ broad bean→ maize) crop sequence in 2014 season. Results indicated that, conservation agriculture (CA) significantly pronounced its superiority reflected on increase maize cone length (cm) by (13.48%, 1.29%), cone weight (g) by (33.62%, 9.5%), biological yield (kg/fad.) by (69.18%, 14.14%) and

Crop sequence		Broad bean after maize (winter, 2013/2014)			
		Seed yield (kg dm/ha)		**Harvest index**	
Treatments		**Observed**	**Simulated**	**Observed**	**Simulated**
CT	NPK	2503	2288	0.256	0.252
	1/2 NPK	2249	2000	0.394	0.32
Semi-CA	NPK	2530	2500	0.25	0.26
	1/2 NPK	2482	2400	0.247	0.241
CA	NPK	3213	3050	0.208	0.202
	1/2 NPK	2973	2950	0.229	0.200
Validation CROPGRO-Model					
RMSE=		**11.70**		**16.79**	
d-State=		**0.999**		**0.999**	
r -Square		**0.974**		**0.926**	
Coincided degree		Good		Good	

The simulation is considered excellent with RMSE<10%, good if 10–20%, fair if 20–30%, poor >30%

Table 7: The coincided between observed and predicted data of seed yield (kg dm/ha) and harvest index of broad bean as affected by tillage system and fertilizer levels through (maize-broad bean-maize) crop sequences.

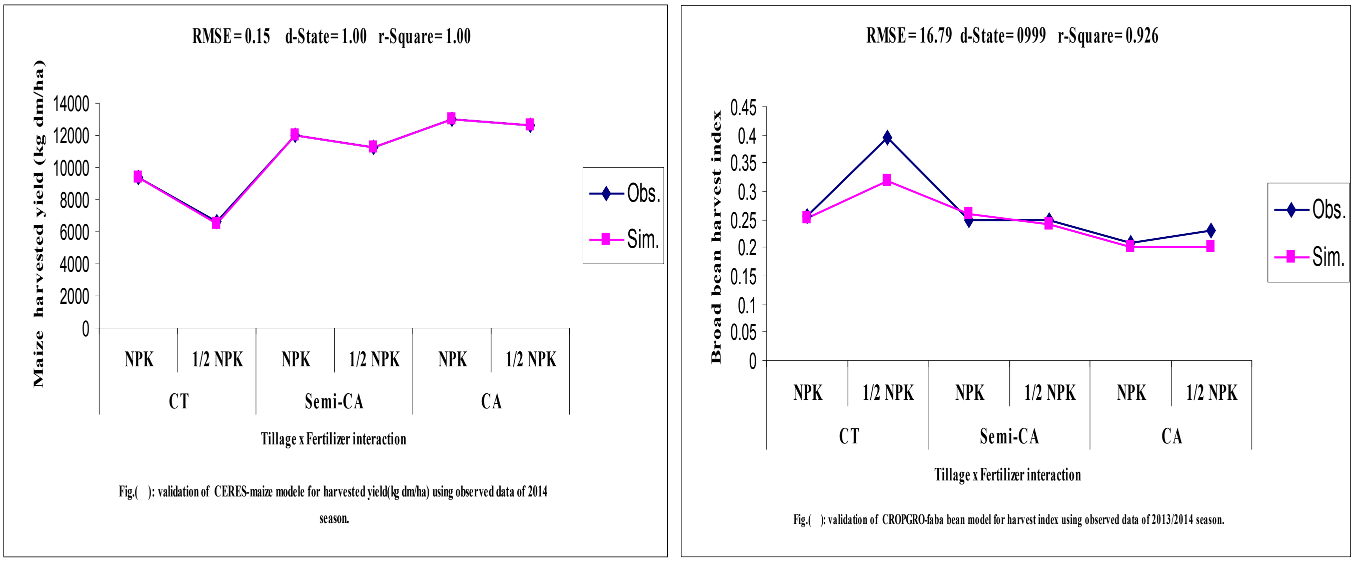

Figure 3: The coincided between observed and predicted data of harvested yield (kg dm/ha) and harvest index of broad bean as affected by tillage system and fertilizer levels through (maize-broad bean-maize) Summer, 2014 season.

grain yield (kg/fad) by (60.75%, 9.73%) as compared with either of Conventional agriculture (CT) or semi-CA respectively.

As for, fertilizer levels, results showed that, there are no significance effect between the recommended doses and the half dose of NPK for maize cone length (cm), cone weight (g). On the other side, the results also, indicated that, the recommended doses of NPK significantly favored maize biological yield (kg/fad), grain yield (kg/fad) and harvest index as compared by 1/2 dose of recommended NPK fertilizers by 5.94%, 12.72% and 6.35% respectively.

In respect of, the effect of first order interaction between tillage system and fertilizer levels, results revealed that, cultivating maize under the condition of conservation agriculture (CA) and fed by the recommended dose or half dose of NPK fertilizers exposed its superiority over than the same level of treatments reflected on gave the greatest value for cone length (27-26.33 cm), cone weight (386.67-381.67 g), biological yield/fed (18661.98-18600.20 kg), grain yield/fed (5981.67-5833.33 kg).

As for harvest index results revealed that the application of Conventional agriculture (CT) + recommended dose of NPK gave, the greatest value (0.358) for that trait and the differences between them reached to the significant level.

On the opposite side, the lowest values for maize pervious traits were resulted under the condition of Conventional agriculture (CT) and fed by the half recommended dose of NPK fertilizers (22.67 cm), (258 g), (9993.33 kg/fad) and (3037.33 kg/fad)and (0.304) respectively.

Validation data by CERES-maize model (summer 2014 season): Results recorded in Table 9 and Figure 4 show that simulation accuracy for maize characters as affected by (tillage x fertilizer) interaction. The results cleared that the calibration indexes (RMSE, D- state and r-Square) showed excellent and good simulation accuracy for both of seed yield (kg/ha) and harvest index (RMSE =0.15 and 12.02), (D-state= 1.00 and 0.999) and (r-Square = 1.00 and 0.790), respectively.

These results in agreement with El-Marsafawy [14] who found that

Treatments		*Cone length (cm)*	*Cone weight (g)*	*Biological yield (kg/fad)*	*Grain yield (kg/fad)*	*Harvest index*
Tillage systems	*Fertilizer level*					
Conventional agriculture (CT)	**100% NPK**	24.33	316.67	12031.70	4312.33	0.358
	50% NPK	22.67	258.33	9993.33	3037.33	0.304
	Mean	23.50	287.50	11012.50	3674.83	0.331
Semi-conservation agriculture (SCA)	**100% NPK**	27.67	385.00	16599.90	5566.67	0.335
	50% NPK	25.00	316.67	16046.70	5200.00	0.324
	Mean	26.33	350.83	16323.30	5383.33	0.33
Conservation agriculture (CA)	**100% NPK**	27.00	386.67	18662.00	5981.67	0.321
	50% NPK	26.33	381.67	18600.20	5833.33	0.314
	Mean	26.67	384.17	18631.10	5907.50	0.318
General Mean TS		25.50	340.83	15322.30	4988.56	0.326
Mean of NPK						
	100% NPK	26.33	362.78	15764.50	5286.89	0.335
	50% NPK	24.67	318.89	14880.10	4690.22	0.315
LSD at 5%						
Tillage systems (TS) =		1. 03	26.71	39.85	71.14	0.004
Fertilizer (F) =		NS	NS	292.11	187.02	0.012
TS x F =		4.06	97.49	601.81	385.3	0.024

Table 8: Effect of tillage system and fertilizer levels as well as the interaction between them on yield and yield component of maize through cropping system of (maize→ broad bean→ maize) in season, 2014.

Crop sequence		*Maize after broad bean (Summer, 2014)*			
		Grain yield (kg dm/ha)		*Harvest index*	
Treatments		*Observed*	*Simulated*	*Observed*	*Simulated*
CT	NPK	9340	9332	0.358	0.357
	1/2 NPK	6578	6560	0.304	0.210
Semi-CA	NPK	12056	12050	0.335	0.335
	1/2 NPK	11262	11258	0.324	0.323
CA	NPK	12955	12950	0.321	0.321
	1/2 NPK	12634	12634	0.314	0.314
Validation CERES-Model					
RMSE=		0.15		12.02	
d-State=		1.000		0.999	
r -Square		1.000		0.790	
Coincided degree		Excellent		Good	

The simulation is considered excellent with RMSE<10%, good if 10–20%, fair if 20–30%, poor >30%

Table 9: The coincided between observed and predicted data of seed yield (kg dm/ha) and harvest index of maize as affected by tillage system and fertilizer levels through (maize-broad bean-maize) crop sequences.

CERES maize-model could be used in the Delta region to simulate maize productivity, water needs through different cropping patterns in Egypt.

Also, Abdrabbo, et al. [15] who found that, the Calibration and validation of CERES-Maize crop simulation model using experimental datasets of years 2011 and 2012 were done successfully giving excellent values for RMSE and d-Stat evaluation indexes.

Discussion

The results revealed that, by applying the conservation agriculture instructions (1. minimum soil disturbance, 2- permanent soil cover with crop residuals or cover crops and 3. Crop rotation with different plant species, which include legumes) starting from summer season 2013 with maize crop through winter season 2013/2014 with broad bean and summer season of 2014 with maize in the same cites, the results recorded gradually improvement started from non-significant differences between the three tested tillage systems on maize studied traits that agree with Peigne [2] who found that, zero tillage with residue retention is characterized by slower initial maize growth, compensated for by an increased growth in the later stages, positively influencing final maize grain yield. They added that, zero tillage with retention of crop residue resulted in time efficient use of resources as opposed to Conventional agriculture. Also, Paz [16] who revealed that, maize yield when cropped under no-till system present higher productivity combined with crop rotation than under continuous cropping; lower productivity tends to occur under Conventional agriculture and the difference in productivity under no-till using crop rotation and continuous cropping is 1,000 kg/ha for maize. Moreover, Zheng [17] founded that, CA practices were significantly higher in maize yield (7.5%) as compared with Conventional agriculture (CT).

In addition, that may be due to improved soil aggregate stability, soil health and quality, reduce erosion and improve water use under CA as reported by Grigoras [18]. Through winter 2013/2014 season with broad bean, started CA or SCA (semi-CA) pronounced their superiority reflecting an increase of almost broad bean traits such as, No. of pods/plant, biological yield/fed, seed yield/fed, and 100-seed

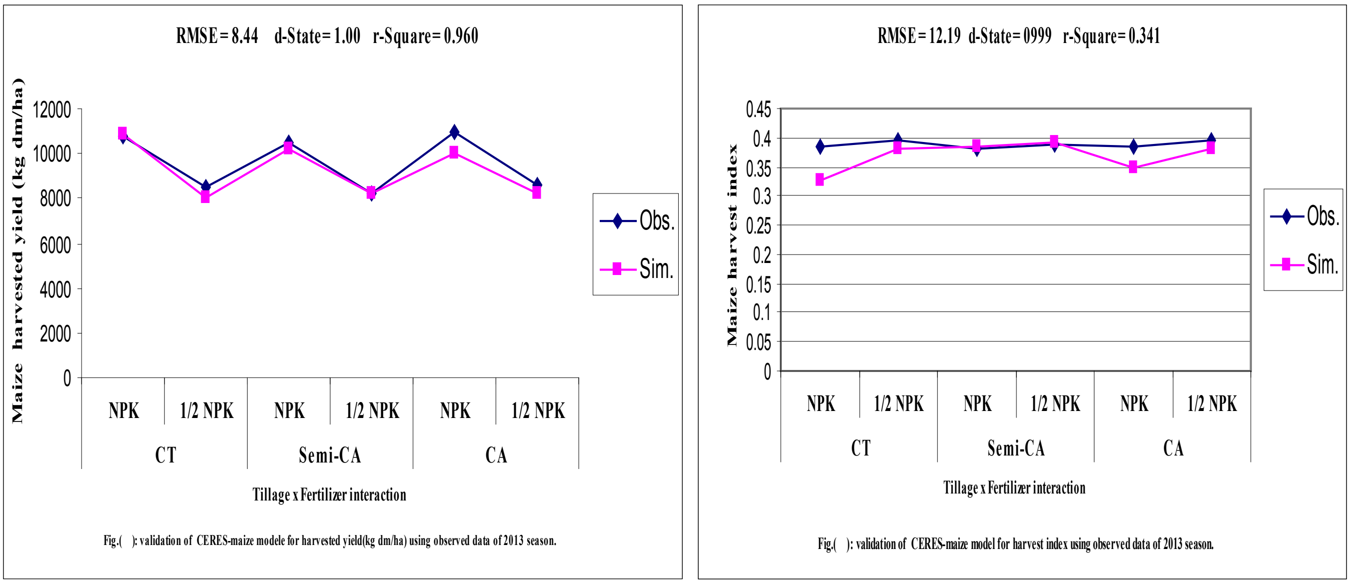

Figure 4: The coincided between observed and predicted data of harvested yield (kg dm/ha) and harvest index of maize as affected by tillage system and fertilizer levels through (maize-broad bean-maize).

weight (g) these results may be attributed to the accumulate effect of nutrients in the soil as appositive effect of CA or SCA compared by (CT) system [19].

After harvesting broad bean and by applying the three tillage systems and cultivate maize, also CA or SCA tillage system led to more positive effect on the studied maize traits, these results probably attributed to the role of the residual organic nitrogen as constructive element come from planting broad bean before.

As for, the results of first order interaction effect between tillage system and fertilizer NPK rate through the crop sequences maize → broad bean→ maize for each crop. It is very interesting to mention that, CA or SCA led to save half dose of NPK fertilizer rate for each crop and that gained by the greatest values of studied traits for maize, broad bean and maize through 2013, 2013/2014 and 2014.

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