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PARAMETERIZATION OF CROPSYST MODEL FOR FOUR WHEAT CULTIVARS GROWN IN EGYPT

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ABSTRACT

The absence of values for wheat cultivars parameters to calibrate CropSyst model can pose as an obstacle to simulate productivity. The objective of this study was to use CropSyst model to quantify a range for calibration parameters for four wheat cultivars grown in 9 growing seasons at 4 governorates in Egypt. Data was collected and used to prepare input data files. These data were: cultivar phenology and productivity at each governorate, as well as soil and weather data. Two parameters were calibrated, i.e. above ground biomass-transpiration (GP1) and light to aboveground biomass conversion (GP2). Goodness of fit test revealed that R^2 and d values were close to 1. The values of MPE, RMSE, and MAE were close to zero, which implied that the calibration procedure was successful to reflect the effect of weather, soil and management on each cultivar and properly simulated productivity. The results also indicated that the range of GP1 value for the four cultivars were between 5.00-10.20 KPa kg/m^3 and the range of GP2 values for these cultivars were between 3.00-8.20 g/MJ. Thus, the obtained set of crop parameters could allow reasonable estimation of productivity for various wheat cultivars at different locations and growing seasons.

Keywords

Above ground biomass-transpiration coefficient; light to aboveground biomass conversion coefficient; Egyptian wheat cultivars; goodness of fit measurements; growing degree days.

1. INTRODUCTION

In Egypt, wheat is the most important food crop and provides almost 35 % of the total food calories of the Egyptian people (Nasser 2010). Temperature and solar radiation effect wheat growing plants. Pre-anthesis and post-anthesis high temperature may have huge impacts upon wheat growth through reduction in photosynthetic efficiency (Wang et al. 2011). Low temperature in the growing season may reduce germination and retard vegetative growth by inducing metabolic unbalances. Significant change in yield of wheat due to variation in temperature and solar radiation has been observed (Ahmed et al. 2010; Li et al. 2010). Thus, different wheat cultivars can perform differently in different weather condition at each site, which reflected on the final yield of these cultivars.

Crop Simulation Models (CSMs) are computerized representations of crop growth, development and yield, simulated through mathematical equations as functions of soil conditions, weather and management practices (Hogenboom et al. 2010). Several CSMs have been developed and used to predict crop yield. As one of the most important CSMs at present is CropSyst model (Stöckle et al. 1999). CropSyst model simulates the soil water budget, soil plant nitrogen budget, crop phenology, canopy and root growth, biomass production, crop yield, residue production and decomposition, soil erosion by water, and salinity. These processes are affected by weather, soil characteristics, crop characteristics, and cropping system management options including crop rotation, cultivar selection, irrigation, nitrogen fertilization, soil and irrigation water salinity, tillage operations, and residue management (Stöckle et al. 2003). The model has been widely applied to cereals and other cropping systems (Confalonieri et al. 2004; Wang et al. 2006; Benli et al. 2007; Singh et al. 2008). CropSyst model was largely used to simulate wheat yield (Pannkuk et al. 1998; Wang et al. 2006; Moriondo et al. 2007; Singh et al. 2008). Furthermore, in Egypt, the model was used to simulate wheat yield (Khalil et al. 2009; Ouda et al. 2010; Ouda et al. 2012; El Baroudy et al. 2013; Ibrahim et al. 2012). However, the absence of values of wheat cultivars parameters to calibrate CropSyst model can pose as an obstacle for young researchers in the field of simulation in Egypt. One of these parameters is above ground biomass-transpiration coefficient (kPa kg/m^3). This value represents the above ground biomass production per meter of transpiration under given conditions of atmospheric vapour density deficit. The other coefficient is light to aboveground biomass conversion (g/MJ). This value represents the above ground biomass production per unit of light intercepted by the crop canopy. Both parameters reflect the ability of the cultivar to produce dry matter and partition it to different plant parts (Stöckle et al. 1999; Stöckle et al. 2003).

Thus, the objective of this study was to use CropSyst model to quantify a range for calibration parameters for four wheat cultivars grown under different agro-climatic conditions in Egypt to be used to simulate productivity.

2. MATERIAL AND METHODS

2.1 Collected Data

2.1.1 Wheat Cultivars Data

Four wheat cultivars were selected, i.e. Giza168, Sakha93, Gemmeza9 and Sids1. These cultivars can be divided to cultivars suitable to be cultivated in all Egypt governorates (Giza168 and Sakha93), cultivar suitable in Nile Delta only (Gemmeza9) and cultivar suitable in Upper Egypt only (Sids1). Four governorates were selected: Kafr El-Sheikh (North Delta, latitude 31.08º N, longitude 30.94º E and elevation 20 m), El-Gharbia (Middle Delta, latitude 30.78º N, longitude 31.12º E and elevation 15 m), El-Minya (Middle Egypt, latitude 27.73º N, longitude 30.84º E and elevation 40 m) and Sohag (Upper Egypt, latitude 26.60º N, longitude 31.65º E and elevation 69 m).

Wheat productivity data for the above mentioned cultivars from 2003/04 until 2011/12 growing seasons were collected from Economic Affairs Sector, which collect data from Agriculture Directorates in the selected governorates. Table (1) presents productivity of these cultivars in the selected governorates and growing seasons.

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Table 1. Wheat productivity (ton/ha) of selected cultivars grown in the selected governorates.

Locations	Wheat Cultivars	2003 /04	2004 /05	2005 /06	2006 /07	2007 /08	2008 /09	2009 /10	2010 /11	2011 /12
Kafr El-Sheikh	Giza168	6.74	6.75	6.73	6.81	6.40	6.44	6.64	6.50	6.50
	Sakha93	6.71	6.67	6.75	6.80	6.40	6.44	6.07	6.39	6.51
	Gemmeza9	--	--	6.76	6.81	6.40	6.48	6.36	6.06	6.51
El-Gharbia	Giza168	6.92	6.84	6.90	6.95	7.08	6.85	6.60	6.70	6.94
	Sakha93	6.73	6.93	6.90	6.95	7.23	6.85	6.20	6.69	6.92
	Gemmeza9	7.47	7.29	6.90	6.95	7.61	6.85	6.34	6.60	6.94
El-Minya	Giza168	7.29	7.08	6.89	7.23	6.53	7.04	6.27	7.30	6.48
	Sakha93	--	--	6.89	7.23	6.63	7.05	6.27	7.43	6.86
	Sids 1	7.50	7.07	6.89	7.23	6.64	7.04	6.27	7.17	6.55
Sohag	Giza168	7.25	6.96	6.31	6.97	6.64	6.65	5.42	6.94	6.86
	Sakha93	--	--	--	6.61	6.64	7.30	5.36	6.83	--
	Sids 1	7.66	7.17	6.00	6.70	6.64	7.05	5.29	6.82	7.18

Source: MALR, (2012). Bulletins of Agricultural Statistics, Arab Republic of Egypt, Ministry of Agriculture and Land Reclamation, the Egyptian Economic Affairs Sector, Central Department of Agricultural Economics & Statistics.

Days to anthesis and to physiological maturity for each cultivar were obtained from Wheat Research Department; Field Crops Research Institute; Agricultural Research Centre in Egypt (Table 2).

Table 2. Days to anthesis, physiological maturity and season length for the selected cultivars.

Wheat Cultivars	Days to anthesis	Days to physiological maturity	Season length (days)
Giza168	97	57	154
Sakha93	95	56	151
Gemmeza9	99	60	159
Sids1	101	56	157

2.1.2 Soil analysis for the selected governorates

Soil analysis in the selected governorates were obtained from Soils, Water and Environment Research Institute; Agriculture Research Centre in Egypt (Table 3).

Table 3. Soil analysis for different locations at different depths.

Locations	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture class	PH
Kafr El-Sheikh	0-35	43.0	25.2	31.8	Clay	7.70
	35-90	46.3	21.8	31.9	Clay	7.50
	90-150	43.8	29.0	27.2	Clay	7.55
El-Gharbia	0-30	42.4	21.3	36.3	Clay	7.72
	30-80	40.5	26.7	32.8	Clay	7.82
	80-150	43.2	29.2	27.6	Clay	7.92
El-Minya	0-25	41.0	25.0	34.0	Clay	7.35
	25-75	40.2	29.7	30.1	Clay	7.70
	75-110	45.0	25.4	29.6	Clay	7.80
Sohag	0-20	42.6	25.3	32.1	Clay	7.82
	20-65	21.8	39.6	38.6	loam	7.75
	65-120	29.6	40.4	30.0	Clay loam	7.80

2.1.3 Weather Data

Weather data for each governorate were collected from Central Administration for Extension, Egypt. These data were daily maximum and minimum temperature, relative humidity and solar radiation for 2003/04 to 2011/12 wheat growing seasons. Seasonal values of these parameters were calculated and presented in Table (4).

Table 4. Seasonal values of maximum, minimum and mean temperature, relative humidity and solar radiation averaged from 2003/04 to 2011/12 growing seasons for different wheat cultivars.

Locations	Wheat cultivars	TMax	TMin	TMean	RH	SRad
Kafr El-Sheikh	Giza168	20.70	13.67	17.19	59.80	15.01
	Sakha93	20.64	13.64	17.14	59.91	14.88
	Gemmeza9	20.87	13.73	17.30	59.52	15.26
El-Gharbia	Giza168	23.33	10.04	16.69	43.43	15.51
	Sakha93	23.24	9.99	16.62	43.61	15.39
	Gemmeza9	23.59	10.17	16.88	42.92	15.73
El-Minya	Giza168	23.70	10.02	16.86	34.43	17.84
	Sakha93	23.60	9.93	16.77	34.62	17.73
	Sids 1	23.89	10.14	17.02	34.09	18.00
Sohag	Giza168	23.75	9.86	16.81	31.69	18.40
	Sakha93	23.64	9.77	16.71	31.88	18.30
	Sids 1	23.95	10.00	16.98	31.36	18.56

TMax = Maximum temperature (ºC), TMin = Minimum temperature (ºC), TMean= Mean temperature (ºC), RH= Relative Humidity (%) and SRad = Solar Radiation (MJ/m^2/day).

2.2 CropSyst Model

CropSyst is a multi-year, multi-crop, daily time step crop growth simulation model, developed with emphasis on a friendly user interface, and with a link to GIS software and a weather generator (Stöckle et al. 1999; Stöckle et al. 2003). Five input data files are required to run CropSyst: Simulation Control, Location, Soil, Crop, and Management files. Definitions, usage, and range of variation of all parameters required by CropSyst are given in the User's Manual (Stöckle & Nelson, 2000) and they are also available in the "Help" facility of the model interface.

2.3 Data Preparation

For each growing season in each location, its weather and soil data were put in its file format. Furthermore, a wheat crop file was prepared for each cultivar in each growing season and location. Harvest index of each cultivar was used as an input in the crop file. Growing degree days to reach four phenological stages were calculated from the observed average temperature data and base temperature for wheat (4.5°C for spring wheat). These stages were days to peak leaf area index, anthesis, maximum grain filling and physiological maturity, and used as input in crop phenology file. Irrigation and fertilizer were assumed to be optimum application in the management file.

2.4 Model Calibration

The calibration of the model consisted of slight adjustments of two crop parameters to reflect reasonable simulations. These adjustments were around values that were either typical for the crop species or known from previous experiences with the model. The first parameter was above ground biomass-transpiration coefficient (GP1, kPa kg/m^3) and the other coefficient is light to aboveground biomass conversion (GP2, g/MJ).

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3. METHODOLOGY

CropSyst model was run using the above mentioned data sets for each cultivar in each governorate and growing season. The calibration parameters, i.e. GP1 and GP2 were modified for each cultivar to predict a value close to the measured wheat yield in each growing season and location.

3.1 Goodness of Fit Analysis

To evaluate the performance of CropSyst model in predicting productivity for each cultivar in the selected growing season and locations, the goodness of fit between the measured and predicted values, were calculated as follows:

3.1.1 Coefficient of Determination (R^2)

R^2 tells us how much better we can do in predicting observation by using the model and computing the simulation by just using the mean observation as a predictor.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2} \qquad (1)$$

Where Oi and Si represent the observed and simulated values, n represents the number of observed and simulated values used in comparison and $\bar{O}$ is the observed average. R^2 takes on values between 0 and 1, a value of 1 indicates a perfect match, and value of 0 indicates no agreement at all

3.1.2 Mean Percentage Error (MPE %)

A positive MPE values provides the averages amount of under-estimation of the calculated values, while a negatives value gives over-estimation.

$$MPE = \frac{\sum_{i=1}^{n}\left(\frac{(O_i - S_i)}{O_i} \times 100\right)}{n} \qquad (2)$$

3.1.3 Root Mean Square Error (RMSE)

It is a frequently used measure of the difference between values predicted by a model and those actually observed from the experiment that is being modelled (Jamieson et al. 1998). The RMSE values can be used to distinguish model performance in a calibration period with that of a validation period as well as to compare the individual model performance to that of other predictive models.

$$RMSE = \sqrt{\left(\frac{\sum_{i=1}^{n}(S_i - O_i)^2}{n}\right)} \qquad (3)$$

3.1.4 Mean Absolute Error (MAE)

It measures the average magnitude of the errors in calibrated and validated data, without considering their direction. It measures accuracy for continuous variables.

$$MAE = \frac{\sum_{i=1}^{n}(O_i - S_i)}{n} \qquad (4)$$

3.1.5 Mean Bias Error (MBE)

It is a measure of overall bias error or systematic error between the observed and the simulated parameters.

$$MBE = \frac{\sum_{i=1}^{n}(S_i - O_i)}{n} \qquad (5)$$

3.1.6 Willmott Index of Agreement (d)

It is the standardized measure of the degree of model prediction error and varies between 0 and 1. A value of 1 indicates a perfect match, and value of 0 indicates no agreement at all (Willmott 1981).

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$$d = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}[(|(S_i - \bar{O})| + |(O_i - \bar{O})|)^2]} \quad (6)$$

After testing the goodness of fit between measured and predicted productivity values for each cultivar, a range of the above mentioned parameters was obtained.

4. RESULTS AND DISCUSSION

4.1 Goodness of Fit Between Measured and Predicted Wheat Yield

4.1.1 Wheat Cultivar Giza168

Results in Table (5) indicated that the predicted values were close to the measured values. R^2 and d values were the close to 1. MPE, RMSE and MAE values were close to zero. Furthermore, MBE values were negative, which indicate that the model underestimate the predicted values.

Table 5. Average measured versus predicted yield for Giza168 and goodness of fit parameters in the studied governorates.

Locations	N	R^2	MPE	RMSE	MAE	MBE	d
Kafr El-Sheikh	9	0.999	0.040	0.005	0.003	-0.003	0.999
El-Gharbia	9	0.999	0.069	0.005	0.005	-0.005	0.999
El-Minya	9	0.999	0.086	0.006	0.006	-0.006	0.999
Sohag	9	0.999	0.086	0.007	0.006	-0.006	0.999

N= No. of observations; R^2= coefficient of determination; MPE= Mean Percentage Error; RMSE= Root mean square error; MAE= Mean absolute error; MBE= Mean bias error; d=Willmott index of agreement.

4.1.2 Wheat Cultivar Sakha93

Regarding to Sakha93, similar results were obtained. MPE, RMSE and MAE values were close to zero and R^2 and d values were close to one (Table 6).

Table 6. Average measured versus predicted yield for Sakha93 and goodness of fit parameters in the studied governorates.

Locations	N	R^2	MPE	RMSE	MAE	MBE	d
Kafr El-Sheikh	9	0.999	0.071	0.007	0.005	-0.005	0.999
El-Gharbia	9	0.999	0.040	0.003	0.003	-0.003	0.999
El-Minya	7	0.999	0.057	0.005	0.004	-0.004	0.999
Sohag	5	0.999	0.000	0.003	0.002	-0.002	0.999

N= No. of observations; R^2= coefficient of determination; MPE= Mean Percentage Error; RMSE= Root mean square error; MAE= Mean absolute error; MBE= Mean bias error; d=Willmott index of agreement.

4.1.3 Wheat Cultivar Gemmeza9

The same trend was observed for Gemmeza9, where MPE, RMSE and MAE values were close to zero and R^2 and d values were close to one (Table 7).

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Table 7. Average measured versus predicted yield for Gemmeza9 and goodness of fit parameters in the studied governorates.

Locations	N	R^2	MPE	RMSE	MAE	MBE	d
Kafr El-Sheikh	7	0.999	0.063	0.004	0.004	-0.004	0.999
El-Gharbia	9	0.999	0.061	0.005	0.004	-0.004	0.999

N= No. of observations; R^2= coefficient of determination; MPE= Mean Percentage Error; RMSE= Root mean square error; MAE= Mean absolute error; MBE= Mean bias error; d=Willmott index of agreement.

4.1.4 Wheat Cultivar Sids1

Similar results were obtained for Sids1, where MPE, RMSE and MAE values were close to zero and R^2 and d values were close to one Table (8).

Table 8. Average measured versus predicted yield for Sids1 and goodness of fit parameters in the studied governorates.

Locations	N	R^2	MPE	RMSE	MAE	MBE	d
El-Minya	9	0.999	0.069	0.006	0.005	-0.005	0.999
Sohag	9	0.999	0.065	0.005	0.004	-0.004	0.999

N= No. of observations; R^2= coefficient of determination; MPE= Mean Percentage Error; RMSE= Root mean square error; MAE= Mean absolute error; MBE= Mean bias error; d=Willmott index of agreement.

Several researchers in Egypt obtained the same trend for RMSE and d values (Ouda et al. 2010; Ouda et al. 2012; El Baroudy et al. 2013; Ibrahim et al. 2012). Furthermore, comparable significant relationships between measured and predicted wheat yield values were obtained by Khalil et al. (2009).

Thus, the calibration procedure was successful to reflect the effect of weather, soil and management on the growing plants of each cultivar and properly simulated growth and productivity of the studied cultivars. Thus, we preceded and quantify the calibration coefficients for each cultivar.

4.2 Calibration Coefficients

4.2.1 Wheat Cultivar Giza168

The growth behaviour of Giza168 was different in the four studied governorates (Table 9). In Kafr El-Sheik (North Delta), growing degree days to anthesis was the highest, growing degree days from anthesis to physiological maturity was the lowest, seasonal GDD was the highest and wheat productivity was the lowest. Furthermore, above ground biomass/transpiration coefficient values (GP1) and light to above-ground biomass conversion values (GP2) was the lowest, which implied that vegetative biomass was higher on behalf of reproductive biomass and final yield. The lowest values of GDD was found at Sohag (South Egypt), which implied that season length is shorter in south of Egypt, compared to north of Egypt as a result of higher temperature. The highest values of GP1 and GP2 were found at El-Gharbia, where GDD to reproductive growth was the highest. However, the highest yield of Giza168 was found in El-Minia (Table 9), which implied that the weather of El-Minia is more favourable for Giza168, which lead to higher biomass accumulation rate.

Table 9. Growing degree days, above ground biomass/transpiration coefficient, and light to above-ground biomass conversion coefficient and measured yield of Giza168.

Locations	GS1 (°C-day)	GS2 (°C-day)	SGDD (°C-day)	GP1 (KPa kg/m^3)	GP2 (g/MJ)	MGY (ton/ha)
Kafr El-Sheikh	1258	871	2129	5.82	3.82	6.61
El-Gharbia	1141	920	2061	10.14	8.14	6.87
El-Minya	1113	913	2026	9.21	7.21	6.90
Sohag	1109	903	2012	8.57	6.57	6.67

N=Number of growing seasons; GS1= GDD to anthesis; GS2= GDD from anthesis to physiological maturity; SGDD= GDD to physiological maturity; GP1=Calibrated above ground biomass/transpiration coefficient values and GP2= Calibrated light to above-ground biomass conversion values; MGY= Measured grain yield.

Confalonieri et al. (2012) stated that vapour pressure deficit is the main factor affecting daily biomass accumulation for wheat. Thus, the lowest yield of Giza168 in Kafr El-Sheikh could be a result of low seasonal temperature and solar radiation values, as well as high relative humidity values. On the contrary, in Sohag, seasonal temperature and solar radiation values are high and relative humidity values are low, which discourage daily biomass accumulation for wheat. Ouda et al. (2013) reported that PG1 and PG2 values for Giza168 grown in El-Behira governorate, located to north of El-Gharbia governorate, were 10.95 KPa kg/m^3 and 8.95 g/MJ, where yield was 7.82 ton/ha.

4.2.2 Wheat Cultivar Sakha93

Similar trend was observed for Sakha93 in Karf El-Sheikh, where growing degree days to anthesis and seasonal growing degree days were high. Growing degree days from anthesis to physiological maturity, GP1 and GP2 were low. The highest values of GP1 and GP2 were found at El-Gharbia, where GDD to reproductive growth was the highest. The highest yield of Sakha93 was found in El-Minia (Table 10).

Table 10. Growing degree days, above ground biomass/transpiration coefficient, and light to above-ground biomass conversion coefficient and measured yield of Sakha93.

Locations	GS1 (°C-day)	GS2 (°C-day)	SGDD (°C-day)	GP1 (KPa kg/m^3)	GP2 (g/MJ)	MGY (ton/ha)
Kafr El-Sheikh	1233	861	2094	5.83	3.83	6.53
El-Gharbia	1115	907	2022	10.20	8.20	6.82
El-Minya	1087	916	2003	9.49	7.49	6.91
Sohag	1083	917	2000	8.87	6.87	6.55

N=Number of growing seasons; GS1= GDD to anthesis; GS2= GDD from anthesis to physiological maturity; SGDD= GDD to physiological maturity; GP1=Calibrated above ground biomass/transpiration coefficient values and GP2= Calibrated light to above-ground biomass conversion values; MGY= Measured grain yield.

Ouda et al. (2013) obtained similar values for GP1 and GP2 for Sakha93 planted in salt-affected soil at El-Sharkia governorate (east of El-Gharbia), i.e. 4.28 KPa kg/m^3 and 2.28 g/MJ, and the final yield was 2.82 ton/ha. The above results implied that GP1 and GP2 were not only affected by weather conditions, but also with soil and management conditions.

The results in Table (9) and (10) implied that weather conditions of El-Gharbia and El-Minia were suitable to Giza168 and Sakha93 to excel and produce the highest potential yield, compared to Karf El-Sheik and Sohag weather conditions.

4.2.3 Wheat Cultivar Gemmeza9

Grain yield of Gemmeza9 was the highest in El-Gharbia, where growing degree days from anthesis to physiological maturity, GP1and GP2 values higher than its counterpart in Kafr El-Sheikh (Table 11). This result proved the previous conclusion that El-Gharbia weather encourages formation of high potential yield of the planted cultivars. Previous research by Ouda et al. (2013) indicated that GP1 and GP2 values for Gemmeza9 planted in El-Shakia governorate (east of El-Gharbia) were 7.75 KPa kg/m^3 and 5.75 g/MJ.

Table 11. Growing degree days, above ground biomass/transpiration coefficient, and light to above-ground biomass conversion coefficient and measured yield of Gemmeza9

Locations	GS1 (°C-day)	GS2 (°C-day)	SGDD (°C-day)	GP1 (KPa kg/m^3)	GP2 (g/MJ)	MGY (ton/ha)
Kafr El-Sheikh	1282	935	2217	5.77	3.77	6.48
El-Gharbia	1165	994	2159	10.14	8.14	6.99

N=Number of growing seasons; GS1= GDD to anthesis; GS2= GDD from anthesis to physiological maturity; SGDD= GDD to physiological maturity; GP1=Calibrated above ground biomass/transpiration coefficient values and GP2= Calibrated light to above-ground biomass conversion values; MGY= Measured grain yield.

4.2.4 Wheat Cultivar Sids1

Sids1 wheat cultivar preformed better at El-Minia governorate as a result of suitable weather condition. Both growth parameters and yield were higher compared to its counterpart in Sohag governorate (Table 12).

Table 12. Growing degree days, above ground biomass/transpiration coefficient, and light to above-ground biomass conversion coefficient and measured yield of Sids1.

Locations	GS1 (°C-day)	GS2 (°C-day)	SGDD (°C-day)	GP1 (KPa kg/m^3)	GP2 (g/MJ)	MGY (ton/ha)
El-Minia	1167	1023	2190	9.22	7.22	6.93
Sohag	1163	1036	2199	8.64	6.64	6.72

N=Number of growing seasons; GS1= GDD to anthesis; GS2= GDD from anthesis to physiological maturity; SGDD= GDD to physiological maturity; GP1=Calibrated above ground biomass/transpiration coefficient values and GP2= Calibrated light to above-ground biomass conversion values; MGY= Measured grain yield.

Bechini et al. (2006) reported that the average value for GP1 and GP2 were 5.8 KPa kg/m^3 and 3.1 g/MJ, respectively for wheat planted in North Italy. Singh et al. (2013) concluded that the average value of GP1 was 7.5 KPa kg/m^3 and GP2 was 3.5 g/MJ for wheat planted in India.

4.3 Quantification of Growth Coefficients

The range of growth coefficients for the four cultivars is presented in Table (13). Results in that table indicated that the range of GP1 value for the Giza168, Sakha93 and Gemmeza9 were between 5.00-10.20 KPa kg/m^3. Furthermore, GP2 values for the above mention cultivars were between 3.00-8.2 g/MJ. The situation was different for Sids1, where GP1 values was between 8.64-9.22 KPa kg/m^3 and GP2 values were between 6.64-7.22 g/MJ. This result implies that high value of growth parameters do not attaining the highest potential yield.

Table 13. Range of growth parameters for the studied wheat cultivars.

Growth Coefficients	Giza168	Sakha93	Gemmeza9	Sids1
GP1	5.82-10.14	5.83-10.20	5.77-10.14	8.64-9.22
GP2	3.82-8.14	3.83-8.20	3.77-8.14	6.64-7.22

GP1 = above ground biomass/transpiration coefficient values and GP2 = light to above-ground biomass conversion values.

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5. CONCLUSIONS

CropSyst model could be satisfactorily parameterized for spring wheat grown in Egypt using existing wheat productivity data collected for purposes other than modeling. The set of crop parameters obtained allowed reasonable estimates of productivity during wheat growth for various cultivars, locations and growing seasons in Egypt. The simulated values were characterized by low estimation errors. This suggests that the proposed values of several cultivars parameters can be used for simulations in similar locations.

This is the first time a multi-year, multi-cultivars, spatially distributed experiments is carried out to analyze the relationships between CropSyst model structure and environmental driving forces. This analysis allowed the attainment of an in-depth knowledge of the behavior of studied cultivars.

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