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Research Article

Evaluation of Yield Prediction Performance of DSSAT CSM-CERES-Wheat Model in Some Bread Wheat Varieties

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Abstract

Product simulation programs with DSSAT are based on the principle of predicting the potentials of yield and other phenological parameters of wheat varieties with different fertilizer application doses in different climatic and soil conditions. For this purpose, different wheat varieties (Bayraktar, Tosunbey) were used in order to test the use of the DSSAT simulation model in semi-arid conditions in the İkizce experimental area of the Haymana District of Ankara Province, Field Crops Central Research Institute, during the 2017-2018 and 2018-2019 periods. The aim of this study is to predict yield in wheat varieties (Bayraktar, Tosunbey) using CERES and CROPGRO sub-models of DSSAT v.4.7.5 simulation model. In the study, the model was run at different nitrogen application doses (0, 6, 12, 18 kg/da) to reveal the yield prediction potential of the wheat cultivars in semi-arid conditions. For the calibration of the model, the grain yield, plant height and Leaf area index (LAI) data obtained were used in the first year of wheat development stage.The accuracy of the model, which was calibrated with the first year data, was tested with the second year data. For Bayraktar variety, the average measured yield obtained from different nitrogen dose applications (N0, N6, N18) for the 2017-2018 period is 373.3 kg/da, the simulated yield is 373.7 kg/da (Due to flood, N12 dose was not taken into consideration during the 2017-2018 period in the simulation), the measured yield for 2018-2019 300. 5 kg/da, the simulated yield was found to be 291.3 kg/da. For the Tosunbey variety, the average yield measured for the 2017-2018 period was 370.0 kg/da, the simulated yield was 338.0 kg/da, the measured yield for the 2018-2019 year was 217.58 kg/da, and the estimated yield was 237.83 kg/da.

Keywords: Crop Simulation Modelling, DSSAT CSM-CERES, Fertilization, Wheat, Yield Estimate

Introduction

The capabilities of the plant simulation models, which have been used since the late 1960s, have been increased over time with the developing technology, and models have been developed for many different plant species. Plant simulation models generally differ from each other in terms of complex equation systems describing the developmental processes of plants and the input parameters they use. Process-based crop models use weather, soil, crop and management information as input to simulate plant development and growth (Asseng et al., 2014; Basso et al., 2016; Uzun and Ustaoğlu, 2022).

There are three different approaches developed to estimate crop yield. These are statistical, biophysical and remote sensing methods. Statistical methods are approaches that reveal the relationships between grain yield and precipitation. The secondary approach is holistic crop simulation models that reveal the relationships between plant-soil atmospheres, integrating information. Hansen and Indeje (2004) summarized the different methods of predicting crop yield without observed rainfall data from weather stations. The four major methods to predict yield in their work were (1) developing nonlinear regression with principal components derived from the GCM output fields, (2) using k-nearest neighbor weighted average yield of the nonlinear-regression modeled yield, (3) executing crop simulation models with weather from weather generators, and (4) executing crop simulation models with daily weather produced by dynamic climate forecast models.

According to Hoogenboom (2000), one of the main purposes of simulation models is to predict agricultural production as a function of soil and climatic conditions in addition to crop management. The product simulation model “Decision Support System for Agrotechnology” (DSSAT) serves different purposes. The main ones are support for product management (Hunkár, 1994; Ruiz-Nogueria et al., 2001; Esetlili et al., 2018); nitrogen fertilizer management practices Gabrielle and Kengni, 1996; Gabrielle et al., 1998; Zalud et al., 2001); irrigation management practices (Ben nouna et al., 2000; Castrignano et al., 1998); precision farming practices (Booltink and Verhagen, 1997; Booltink et al., 2001; Uzor-Totty., Oyegun 2020); on climate change issues (Iglesias et al., 2000; Semenov et al., 1996; Gürkan et al., 2021); It is widely used in yield estimation (Landau et al., 1998; Saarikko, 2000); in yield sustainability (Hoffmann and Ritchie, 1993). Pecetti and Hollington

(1997), stated that “Crop Environment Resource Synthesis” (CERES-Wheat) model can be used in Mediterranean climate conditions.

There are many studies conducted with plant simulation models in the international arena for different plant species. The use of plant models has been increasing in Turkey in recent years. Plant simulation models have been used in some studies on corn, wheat, barley and cotton in our country. The DSSAT plant simulation model is called Decision Support Systems for Agricultural Technology Transfer. This model first appeared in the 1980s, and the latest version (DSSAT 4.7.5) was published in 2019. (Jones et al. 2003; Hoogenboom et al. 2019). The advantage of this model over many other models is that it allows working with a large number of plants. In addition, the model also includes other models responsible for other works. The DSSAT plant simulation model includes models developed for different plants such as CERES, NWHEAT, Crop Growing Model (CROPGRO), Sugarcane growing model (CANEGRO) and potato growth model (SUBSTOR). While the CROPGRO model within DSSAT is a model for carbon assimilation in photosynthesis, the CERES model is defined as a radiation-based model calculated using the insolation data of biomass.

There are different auxiliary programs developed to support the users within the model. These are long years analysis, economic analysis and crop rotation analysis. Akalın (1997), made regression modeling with meteorological variables for the estimation of wheat yield. Güler (1987), investigated the relationship between wheat yield and climate factors in Central Anatolia and determined the factors affecting yield. Özkan and Akçagöz (2002) used climate parameters to determine wheat, corn and cotton yields in Çukurova Region. They created 27 variables by considering the climate data and the plant growing period, and they searched for a statistical relationship between these variables and yield values. during 1975-1999. According to the statistical results, the R2 value was 0.46 for wheat, 0.57 for corn and 0.74 for cotton. They stated that the most important factor in wheat, corn and cotton is the air temperature at the date of sowing, flowering and harvest in Çukurova. In the field trials conducted in Çukurova University Faculty of Agriculture between 2000-2002, each year for the wheat plant; Physiological death date, maximum leaf area index, minimum leaf area index, harvest index, maximum photosynthesis rate, respiration rate and leaf area index constant data were determined. As a result of the comparison of the daily photosynthesis rate values with the observed values; concordance ($r=0.95$, $p<0.01$) was determined to be significant. In the evaluation of efficiency, for the models used, $r=1.00$, $p<0.01$; $r=0.98$, $p<0.05$ was found. The results showed the usability of these models in wheat yield estimation (Mujdeci et al. 2005). Schulthess et al. (2013) investigated the yield gap in their study and its usability in developing optimum plant breeding recommendations for farmers. When compared to statistical yield information at four districts, the remote sensing-based method proved to be reliable, with relative errors below 10 percent in most cases. Moreover, greenness index (GI) was also used in gross primary production (GPP) approximation, and yield estimates using this method also provided reasonable accuracy (Alganci et.al., 2014).

According to the results of the analysis carried out on the test plots, use of digital photo-based CC rather than the fraction of fPAR in the LUE model provided the most accurate yield estimates. It produced less than 5 percent relative error in cotton and maize test parcels. In general, the CC – SVI relationship showed high linear correlation, with a range of 0,825 – 0,980 R2 in all test parcels. Crop specific regression equations derived from these relationships enabled yield estimates at the parcel level across the study area. When compared to statistical yield information at four districts, the remote sensing based method proved to be reliable, with relative errors below 10 percent in most cases (Algancı, U., 2014).

They used the HybridMaize plant simulation model to estimate the potential yield of maize in northwestern Bangladesh. This region is a fertile region where farmers get high yields of up to 12 tons/ha. With the model, an average of 12.87 tons/ha was calculated (Lobell, 2013), in her review, reported that field trials and simulation studies are useful tools for understanding yield gaps, but it is not easy to upgrade these approaches to small scales to evaluate the entire region. Sibley et al. (2014) conducted a comprehensive study to compare 3 methods that would not require local calibration in 134 irrigated and 94 dry corn (Zea mays L.) fields grown for 4 years in Nebraska. Balaghi et al. (2008) created regression models using in-season total NDVI and meteorological data (temperature, precipitation) to predict wheat yield in Morocco. Şaylan et al. (1998), The AquaCrop model developed by Food and Agriculture Organization (FAO) is used in the development of optimum crop management practices, the development of irrigation strategies in water-limited conditions, the comparison of actual yield and potential yield, the research of the effects of climate change on food production, and the evaluation of the reactions of crops to environmental changes (Raes, 2009). Zhang W. et al. (2013) evaluated the performance of the FAO-AquaCrop model on winter wheat in the southern Loess plateau of China. Biomass, percentage of vegetation, soil water content and grain yield were estimated from the experimental fields between 2004-2011 and were used for calibration and validation of the model.

Purpose, Rationale and Objectives of the Study

With the increasing population, the need for food is increasing day by day. Pre-harvest yield estimation and possible yield calculations are important for the country's economy today. The fact that there are many factors affecting the yield makes it difficult to create a healthy foresight. The most important factors affecting plant productivity are seed genetic structure, soil characteristics, agricultural technique and climatic conditions. Contrary to other factors, climatic conditions stand out as a factor that cannot be completely interfered with and seriously affects productivity.

Within the framework of the general objectives of meeting the increasing demand for agricultural products over the years and using the resources correctly, purpose of this study can be listed as follows:

- To determine the relationships between climate, soil, cultivation technique and plant,
- Estimating yield in a short time and saving costs instead of long-term trial studies.
- To determine the cultivation areas of the products that the Ministry needs in the products studied and to increase the knowledge for the yield estimation study and to create regular estimation reports.To determine research and publication priorities for early yield estimation in wheat.
- The main purpose of the yield estimation study using the DSSAT plant simulation model is to reveal the yield estimation capacity of the DSSATv.4.7.5-CSM-CERES-Wheat model, to evaluate the relationships between wheat varieties (Bayraktar-Tosunbey) with different parameters in different cultivation techniques and different nitrogen dose applications.

Material and Method

Establishing of the Experiment

Agrometeorological simulation model DSSAT-CSM CERES-Wheat was used for wheat yield estimation. In order to obtain the data to be used in the model, a field trial was established for two consecutive years (2017-2018 and 2018-2019) in the Ankara-İkizce Research Farm of the Central Crops Research Institute (TARM) (bottom left 390 36' 53"N, 320 40). ' 45" E; upper right 39°36' 59"N, 320 40' 47" E altitude: 1060 m.) (Fig.1). According to the experimental independent blocks trial design, the control plot is without fertilizer, Bayraktar and Tosunbey (T. aestivum) for both bread wheat varieties at different nitrogen application doses (0,6,12,18 kg/da) compared to the optimum (12 kg/da) application without fertilizer.) based on the nitrogen level, 50% reduced (6 kg/da) and 50% increased (18 kg/da) fertilizer application. For the 2017-2018 application, the parcel area in the trial is 26.5 m.* 9.45 m. = 250 m2, determined as 30 m* 3m= 90 m2 for the year 2018-2019, plant density 397 units/m2, planting depth 5 cm. has been applied. As a base fertilizer, 14 kg/da DAP was applied with planting. Ammonium nitrate top fertilizer application at different fertilizer application doses (0,6,12,18 kg/da) was calculated for each parcel (250 m2) and applied in April (10.04.2018) (Fig. 2). Plant parameters which were collected for Bayraktar and Tosunbey wheat varieties at different phenological development stages (bringing (Z-23), stalking (Z-30), grain binding (Z-41), flowering (Z-60), Physiological Maturity (Z-91) and harvesting) maturity (Z-94)) used in the DSSAT Simulation program. In order to determine the yield at the harvest, the ears were cut by the frame (0.50 m. * 0.50 m. = 0.25 m2), dried in an oven at 80°C and calculated (gr/m2) and converted into a yield per decare (kg/da). The NDVI values were calculated using the GreenSeeker device, and the Leaf Area Index (LAI) and the percentage of coverage (%) values were calculated using the GreenCroper program on a digital picture taken over an area of 0.25 m2.

Data Collection from the Trial Area

2-year field trial data were used to test the predictive capacity of the DSSAT CSM-CERES-Wheat model in wheat under Haymana conditions (2017-2018, 2018-2019). For the calibration of the model, grain yield, leaf area index (LAI) and plant height data obtained in the first year wheat development stage were used. The model was run at different nitrogen application doses (0,6,12,18 kg/da) to reveal the yield prediction potential of wheat under semi-arid conditions. As field observations, the data to be collected to be used in the DSSAT model from the trial area, sowing time, emergence time, number of plants in m2, tillering, stemming, earing, flowering and physiological maturity times, flowering period, fertilizer amounts and times given, plant height, Leaf Area Index (LAI), percentage of coverage, NDVI, data to be collected at harvest were determined as grain yield, biomass, number of ears per m2 and harvest index.

Fig. 1. Experimental Area (İkizce-Haymana/ANKARA)

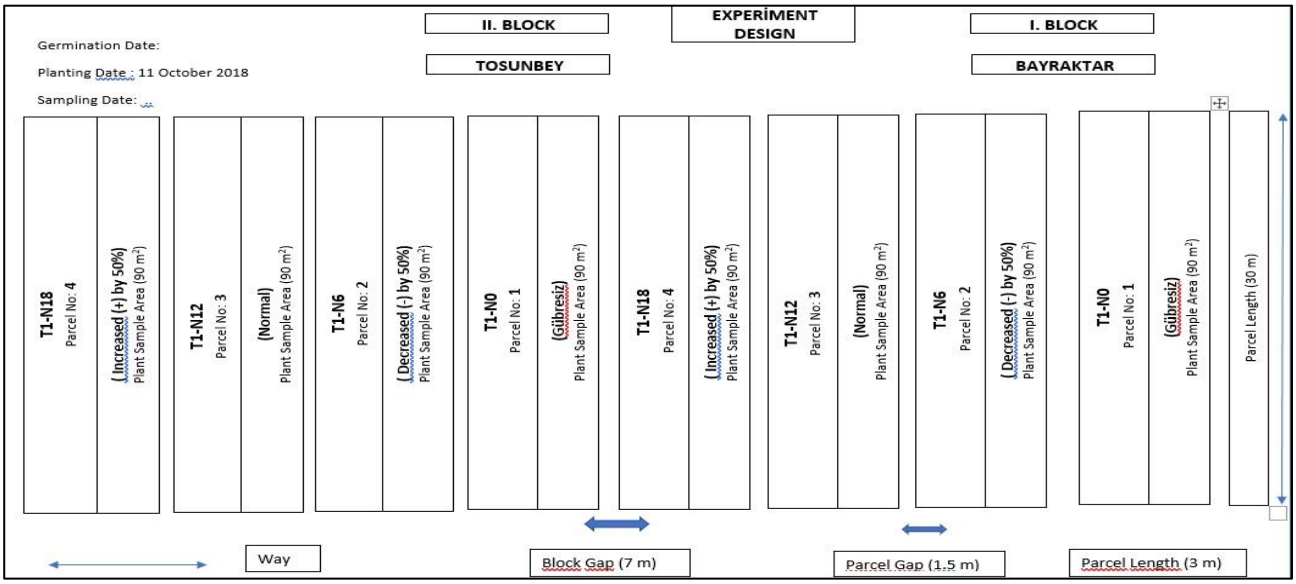

Fig. 2. Experiment Pattern (Haymana 2018-2019)

Table 1. Haymana-İkizce Experimental Area, 2015 Soil Analysis Results.

Location	Depth (cm)	Sandy (%) Tüzüner (1990)	Silt (%) Tüzüner (1990)	Clay (%) Tüzüner (1990)	Texture Tüzüner (1990)	Field Capacity (%) Tüzüner (1990)	Wilting Point (%) Tüzüner (1990)	Volume Weight (g/cm³) Tüzüner (1990)	Hydraulic Conductivity (cm/h) Tüzüner (1990)	Thick Sand	Fine Sand
Haymana Pasture	0-30	15.8	41.5	42.7	SİC	32.90	14.76	1.22	0.05	11.84	3.97
Haymana Pasture	30-60	9.8	37.7	52.5	C	38.55	18.42	1.17	0.76	8.55	1.24
Haymana Pasture	60-90	10.8	33.9	55.3	C	39.08	18.84	1.17	0.71	9.20	1.61

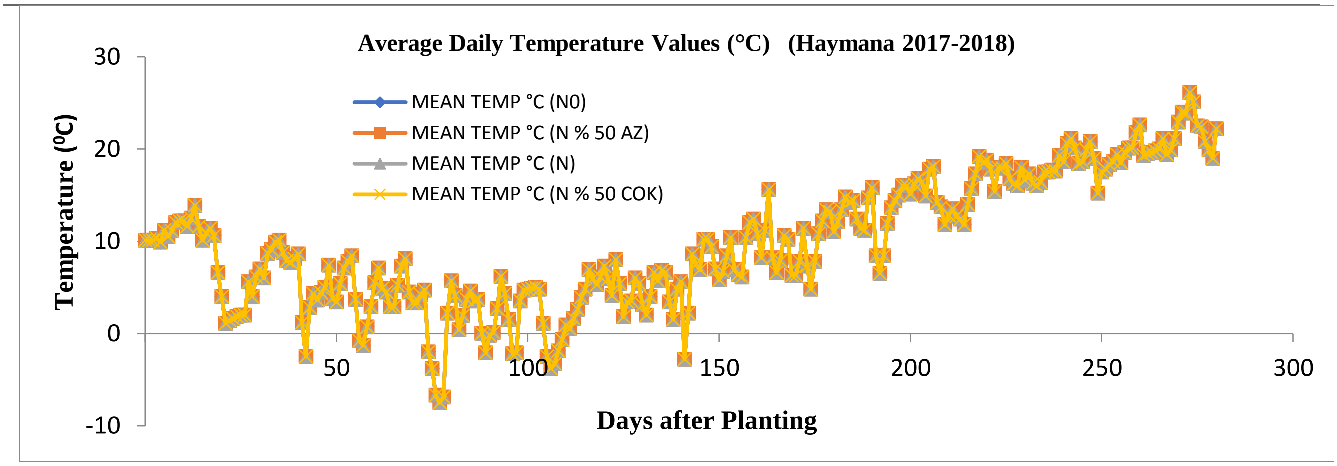

Fig. 3. Haymana Average Daily Temperature (°C) Values (2017-2018).

Soil Data

Soil samples were taken from 0-30, 30-60, 60-90 cm depths before planting. The physical structure of the soil was determined from the samples taken (Table 1). In addition, soil samples were collected from the same depths in different phenological periods during the development period and the moisture determination was made in the soil at % gravimetrically. These obtained data were converted into the volumetric percentage required for the model and used for model calibration. In the DSSAT model, soil horizon data, upper and lower horizon depths, sand clay silt percentages, bulk weight, organic carbon, PH, aluminum saturation and root density information are used as inputs in the soil submodule. Program for estimating soil water submodel parameters; It uses data on albedo, runoff curve number, upper limit of change in the first stage of soil evaporation, drainage coefficient and layer parameters of lower soil water limit for plant growth, upper drained soil water limit, saturated soil water content, and relative root growth spread (Ursayev et al. et al. 2003).

Climate Data

The daily climate data of the experimental area for the years 2017-2018 and 2018-2019 were obtained from the

General Directorate of Meteorology (MGM). In this context, daily maximum and minimum temperature values (0C) (Fig. 3) (Fig. 4), precipitation values (mm.) and solar radiation (MJ.m-2) values and the calculated sunshine durations were used in the project (Parcel temperature values corresponding to different fertilizer applications obtained from the program).

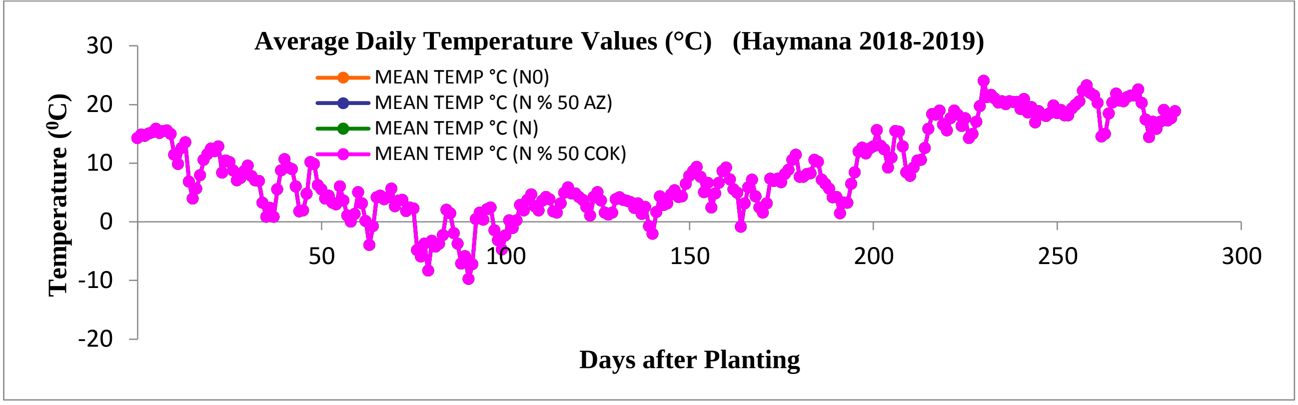

Fig. 4. Haymana Average Daily (°C) Temperature Values (2018-2019).

DSSAT v.4.7.5 CSM-CERES-Wheat Model

Agrotechnology Transfer, was first developed in the 1980s, and the current DSSAT 4.7.5 version was published in 2019 (Jones et al. 2003; Hoogenboom et al. 2019). DSSAT Model used for yield estimation. of Cereals, Legumes, Oil Crops, Tuberous Crops, Fiber Crops, Forage Crops, Sugar Crops, Fruits, Vegetables Wheat Beans Sunflower Potatoes Cotton Clover, Sugar Beet, Citrus, Tomato, Barley, Broad Bean, Canola, etc. (Gurkan, H., 2019). The most important aspect of the DSSAT plant simulation family that distinguishes it from many other models is that it allows to work on a large number of plants. Another important element that distinguishes the model family from other models is that it contains different models. The DSSAT plant simulation family includes models customized for different plants such as CERES, NWHEAT, CROPGRO, CANEGRO, CASUPRO and SUBSTOR. (Hoogenboom et al., 2003). While the CROPGRO model in the DSSAT model family is a model based on carbon assimilation performed in leaves during photosynthesis, the CERES model is defined as a radiation-based model with unit biomass calculation obtained by insolation. There are also different utilities that can support users within the DSSAT plant simulation model. Within the model; Analyzes such as long-term analysis, economic analysis and crop rotation are also allowed.

Obtaining Yield Parameters and Comparison of Simulation Results Yield parameters were collected at different nitrogen application doses (N0, N6, N12, N18) for Bayraktar and Tosunbey bread wheat cultivars during the 2017-2018 and 2018-2019 development periods. The obtained results were used as input in the DSSAT simulation model. The validation indices obtained from the simulation results gave good results for these phenological parameters. The fact that the simulation values calculated with the DSSAT 4.7.5 CERES Wheat submodule and the observed phenological plant observation values are close to each other is important for the model to predict correctly. In this respect, RMSE values obtained as a result of simulation evaluations are important. A RMSE value of <10% means that the simulation is very good, RMSE= 10-20% means good, RMSE= 20-30% Medium, and RMSE= >30 means that the simulation is poor. Using the DSSAT v 4.7.5 CSM-CERES model, the best results were obtained from yield (kg/da), plant height (cm.), Leaf Area Index (LAI) and Harvest Index (% HI) for 2017-2018. Harvest Index (% HI), (RMSE= 0.064), which is one of the closest phenological parameters observed in Bayraktar cultivar during the 2017-2018 development period and estimated by simulation, took the first place, followed by Maximum Leaf Area Index (Max-LAI) (RMSE). = 1.670) and Plant Height (cm.) followed by (RMSE= 7.313) (Fig. 5). Considering the 2017-2018 grain yield results, it was observed that the simulation results obtained from the model under different fertilizer dose applications did not provide the desired harmony with the observed data. Especially at N12 nitrogen application dose, in Haymana semi-arid anhydrous conditions, Bayraktar showed a yield well above its own potential in arid conditions (7200 kg./ha). The biggest factor in this was that the precipitation in the 2017-2018 development period followed a course close to the ideal. Bayraktar variety received a lot of precipitation especially in May, which caused this variety to exceed its yield potential. While the % soil moisture values obtained from the gravimetric soil analyzes performed on the soil samples taken from different depths (0-30, 30-60, 60-90 cm.) at different times of the development period show low values, regular and excessive precipitation in the precipitation regime in May is much more than expected from the Bayraktar variety. resulted in a higher yield potential. While the simulation application index values obtained from other nitrogen application doses (N0, N6, N18) gave good results, the N12 application dose did not give a positive result in terms of yield estimation in general. This fluctuation in the grain yield estimation in the simulation led to great differences between the tillering (RMSE= 1526.0 kg/ha) and the above-ground biomass yield estimation (RMSE= 9633.627) and the index values used in the model's accuracy estimation.

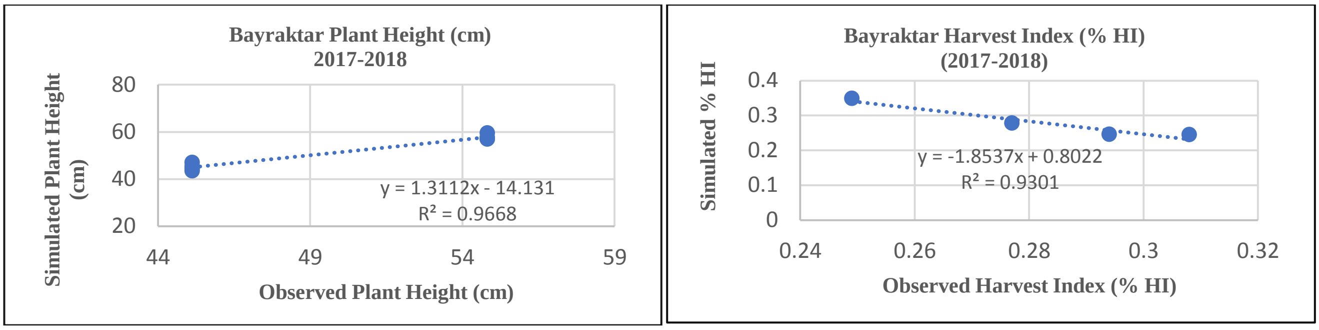

Fig. 5. Simulation evaluations for plant height and harvest index for Bayraktar variety (2017-2018)

Simulation Evaluations for Yield Parameters Results (2017-2018).

In the calibration of the model, the simulated values were compared with the observed values for bread wheat Bayraktar and Tosunbey cultivars, taking into account the average yield parameters in different development periods (2017-2018, 2018-2019) Considering the 2017-2018 simulation comparison results for Bayraktar variety, it was observed that the simulation average results obtained at other doses (N0, N6, N18) were very close to each other) (Table 2) (Table 3), especially by neglecting the N12 optimum dose in the estimation of yield. (The parcel was damaged due to flooding at the dose of N12 and was not taken into account in the simulation, since no observations were received).

The comparison results (2017-2018) of plant height, leaf area index and harvest index, which are other yield parameters, were found to be close to each other in the estimation (Table 4). Considering the 2018-2019 comparative results, values close to each other in grain yield and plant height leaf area index values were calculated (Table 5).

Table 2. According to nitrogen application doses (Average) comparison results of basic development and growth variables measured and simulated (Bayraktar 2017-2018).

Variety	Estimated (Simuled)	Measured
Yield (N_{12} Dose neglected)	373.7	373.3
Plant Height (cm)	45.12	45.03
Biomas (kg/da)	1413.1	2324.2
Laeaf Area Index (LAI)	3.23	2.27
Harvest Index (%)	0.280	0.282
Tillering Number (Number of plant/ m^2)	1918	587

* *Yield evaluation was made by considering the average yield obtained from N_6 and N_{18} Fertilizer doses.*

Table 3. According to Nitrogen Application doses (Average) comparison results of basic development and growth variables measured and simulated (Bayraktar 2018-2019).

Variable	Estimate (Simulated)	Measured
Yield	291.3	300.5
Plant Height (cm)	54.82	57.75
Biomass (kg/da)	596.23	1119.6
Leaf Area Index (LAI)	1.68	1.84
Harvest Index (%)	0.442	0.152
Tillering Number (Number of plant/ m^2)	1736	1136

Table 4. According to phenological periods average yield parameters obtained at different nitrogen application doses (N0, N6, N12, N18) for the 2017-2018 year for Bayraktar variety

Date	Plant Development Period (Day)	Growth Period (Day)	Biomass (kg/da)	Number of Plants / m^2 (Avg.)	Plant Height (cm.)	Grain Yield (Kg/da)	LAI (Ort.)	Harvest Index (Avg.)	Spike (Number /m^2)	Covering (%)
24.10.2017	0	Sowing	-	0.0	0.0		0.0			0.0
31.01.2017	68	Germination	-	36.0	6.0		0.34			15.75
01.03.2018	127	Tillering	-	328.0	11.0		1.40			49.0
22.03.2018	149	Bolting	86.89	724.0	19.0		1.50			51.36
10.04.2018	169	Flowering Beginning	289.44	776.0	33.0		2.91			75.43
25.04.2018	194	Flowering	379.24	652.0	49.0		2.94			76.71
08.05.2018	207	Earing	569.88	592.0			3.01			76.36
28.05.2018	227	Grain Filling	965.96	564.0	90.0		3.78			83.05
13.06.2018	244	Milking	2563.28	1028.0	94.0		2.31			68.45
18.07.2018	280	Hasat	2324.23	-	79.0	460	-	19.79	164	

Table 5. According to phenological periods average yield parameters obtained at different nitrogen application doses (N_0, N_6, N_{12}, N_{18}) (Bayraktar, 2018-2019

Date	Development Period (Day)	Growth Period (Day)	Biomass (kg/da)	Number of Plants / m^2 Avg)	Plant Height (cm.)	Grain Yield (Kg/da)	LAI (Ort.)	Harvest Index (Avg.)	Spike (Number /m^2)	Covering (%)
11.10.2018	0	Sowing	-	0.0	0.0		0.0			0.0
27.11.2018	16	Emergence	-	372.0	8.75		0.30			14.0
20.02.2019	139	Germination	40.24	468.0	9.67		0.32			29.75
28.03.2019	176	Tillering	196.08	804.0	14.25		1.48			50.32
30.04.2019	210	Bolting	250.01	1676	56.75		3.37			79.23
15.05.2019	225	Flowering Beginning	662.40	1696	82.5		3.01			76.36
30.05.2019	240	Flowering	2224.92	1632	99.25		1.88			60.79
18.06.2019	259	Earing	2436.92	1276	96.25		1.70			56.81
25.06.2019	266	Grain Filling	2047.60	1160	94.50		2.65			73.32
20.07.2019	291	Harvest	2605.08			308.06		15.30	495	

Table 6. According to nitrogen application doses (Average) comparison results of basic development and growth variables measured and simulated (Tosunbey, 2017-2018)

Variable	Simulated	Measured
Yield	338.0	370.0
Plant Height (cm)	44.49	50.69
Biomass (kg/da)	1254.6	2328.9
Leaf Area Index (LAI)	3.10	3.70
Harvest Index (%)	0.270	0.276
Tillering Number (Number of plant/ m^2)	1419	794.5

Table 7. According to nitrogen application doses (Average) comparison results of basic development and growth variables measured and simulated (Tosunbey 2018-2019).

Variety	Simulated	Measured
Yield	237.83	217.58
Biomass (kg/da)	1222.8.	2863.9
Leaf Area İndex (LAI)	3.38	3.88
Harvest Index (%)	0.195	0.203

Table 8. According to phenological periods average yield parameters obtained at different nitrogen application doses (N_0, N_6, N_{12}, N_{18}) (Tosunbey, 2017-2018)

Date	Development Period (Day)	Growth Period (Day)	Biomass (kg/da)	Plants/ m^2Avg.)	Plant Height (cm.)	Grain Yield (Kg/da)	LAI (Avg.)	Harvest Index (Avg.)	Spike (Number/m^2)	Covering (%)
24.10.2017	0	Sowing		0.0						
31.01.2018	68	Germination	-	36.5	0.0		0.0			0.0
01.03.2018	127	Tillering	-	376	8.75		0.30			14.0
22.03.2018	149	Booting	40.24	608	9.67		0.32			29.75
10.04.2018	169	Flowering Beginning	196.08	1168	14.25		1.48			50.32
25.04.2018	194	Flowering	250.01	1328	56.75		3.37			79.23
08.05.2018	207	spiking	662.40	976	82.5		3.01			76.36
28.05.2018	227	Grain Filling	2224.92	728	99.25		1.88			60.79
13.06.2018	244	Milking	2436.92	1224	96.25		1.70			56.81
18.07.2018	280	Harvest	9315.76	494	79.0	420		27.62	206	

Considering the 2017-2018 simulation comparison results for the Tosunbey variety, it was observed that the simulation results obtained in the yield estimation were very close to each other. The comparison results of plant height, leaf area index and harvest index, which are among other yield parameters (Tablo 6), were found to be close to each other in the estimation (Table 7). Considering the 2017-2018, 2018-2019 comparative results, close values were calculated in the grain yield, leaf area index and harvest index (Table 8) (Table 9).

Calibration and Evaluation of the Model.

Three different methods are used in the evaluation of simulation results for yield results.

- **I.Method :** The sum of the squared difference (RMSE) between the simulation values and the observed values is calculated as a % value. For this, the following formula is used (Loague K.; Green R., 1991).

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

n= Number of Observations
P_i = Estimated Value
O_i = Observed Value
M= Observed Average Value
Evaluation of simulation results ;

Calculated RMSE value: “Very Good” if RMSE < 10%, “Good” if RMSE is 10-20%, “Medium” if RMSE is 20-30%, and “Poor” if RMSE >30 is used.

- **II.Method :** Calculation of the Model Consistency Index value (d) (Wilmott et al., 1985).

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

n=Number of Observations
P_i = Estimated Value
O_i= Gözlenen Değer
P'_i = P_i - M
O'_i= O_i – M

The fact that the calculated Model Consistency Index value (d) is close to 1 means that the simulation is very good since the observed value and the estimated value are close to each other.

- **III. Method :** The larger the Correlation Coefficient r^2 (Coefficient Correlation) obtained from the regression equation between the observed (X) and the predicted (Y) value (closer to 1) means the better the simulation will be.

Simulation Evaluations for Bayraktar and Tosunbey Varieties

The DSSAT model estimated yields for Bayraktar and Tosunbey bread wheat varieties using the model inputs under different nitrogen dose applications for two different production years. When the differences between the values found as a result of the simulation and the actual values measured were examined, the average relative error rates differed according to the applied nitrogen doses. The relative error %, which is generally shown as negative (-), indicates that the simulated efficiency value is lower than the actual measured value, and the positive (+) measured value means that the simulated efficiency is higher than the actual value. The more healthy the yield values in field conditions are collected on the basis of parcels and expressing the whole parcel, the closer the real yield values and the simulation values calculated by the model will be. In the project study, since the parcel yield values were calculated over the frame area (0.50 m * 0.50 m = 0.25 m^2), and then converted to unit area (m^2) and acre (1000 m^2), there were differences between the simulated yield result and the actual yield result.The fluctuations in the precipitation regime in the first year and the flooding of the parcel in the second year and the increase in rye density in the parcel were effective in the formation of this yield difference. In the comparison of model and observation values, 2018 and 2019 grain yield values were used for different nitrogen dose applications (Fig. 6). Although it varies according to different nitrogen application doses, the relative error values between 2018 and 2019 different nitrogen dose applications for Bayraktar variety were between -94.69% and +13.16%, and the relative average error values for the same applications varied between -51.85% and +8.53%. The mean relative error values for different years ranged from -29.00% to +4.79% (Table 10). For the Tosunbey variety, the relative error % values between different nitrogen dose applications in 2018 and 2019 varied between -67.36% and +37.09%, and the relative average error values for the same applications varied between -57.09% and +21.36%. The mean relative error values for different years ranged from -24.39% to +38.14% (Fig. 7) (Table 11).

The validation indices obtained from the simulation results in different nitrogen applications gave acceptable results for these phenological parameters. The fact that the simulation values calculated with the DSSAT v4.7.5 CERES-Wheat submodule and the observed phenological plant observation values were close to each other, was found to be important for the model to predict correctly. In this respect, RMSE values obtained as a result of simulation evaluations are important. Harvest Index (% HI) (RMSE= 0.064) was the closest phenological parameters observed in Bayraktar cultivar and estimated by simulation during the 2017-2018 development period, followed by Maximum Leaf Area Index (Max-LAI) (RMSE= 0.064). 1.670) and Plant Height (cm.) followed (RMSE= 8.450) (Table 12)

Using the DSSAT v.4.7.5 CERES-Wheat model in the analysis, the best results were obtained from the yield (kg/da), plant height (cm.), Leaf Area Index (LAI) and Harvest Index (% HI) values for the year 2017-2018 (Fig. 8).

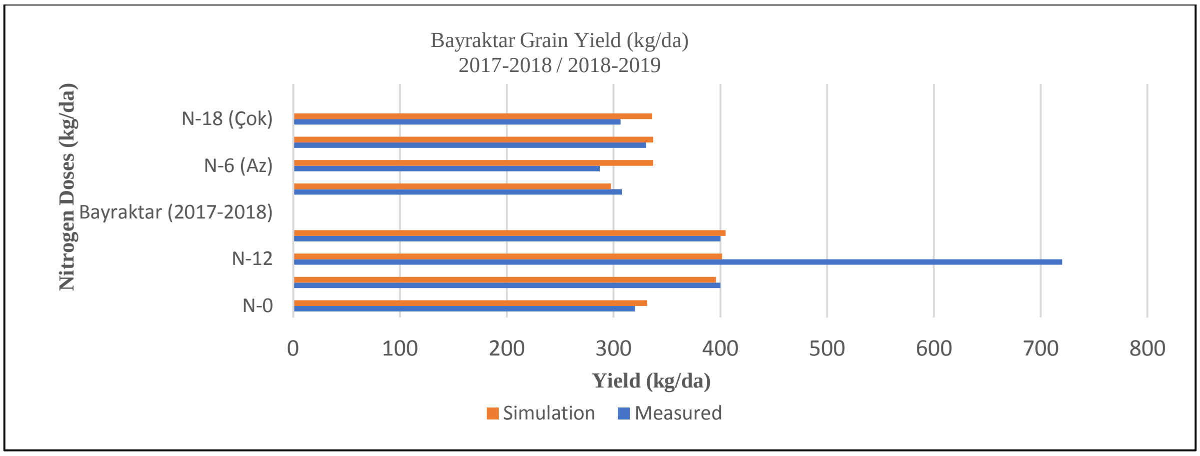

Fig. 6. Grain yield results at different nitrogen dose applications (kg/da) (Bayraktar 2017-2018 / 2018-2019).

Table 10. Simulated and measured yield values for Bayraktar (kg/da).

Simulated and Measured Yield (kg/da) Values for Bayraktar (2017-2018 / 2018-2019)							
		2017-2018			2018-2019		
Applications	**Simülayon**	**Measured**	**Estmate %**	**Simülayon**	**Measured**	**Estmate %**	**Average Error (%)**
N0	**308.0**	**320.0**	**-3.89**	**307.7**	**267.2**	**+13.16**	**+8.53**
N6	**363.9**	**400.0**	**-9.92**	**287.2**	**302.0**	**-5.15**	**-7.54**
N12	**369.8**	**720.0**	**-94.69**	**330.5**	**300.7**	**+9.01**	**-51.85**
N18	**372.0**	**400.0**	**-7.52**	**306.6**	**300.0**	**+2.15**	**-4.83**
Ortalama Hata %	**348.0**	**373.3**	**-29.00**	**333.0**	**292.5**	**+4.79**	**-13.92**

* *The dose (N_{12}) was neglected no observation because of the flood (2107-2018)*

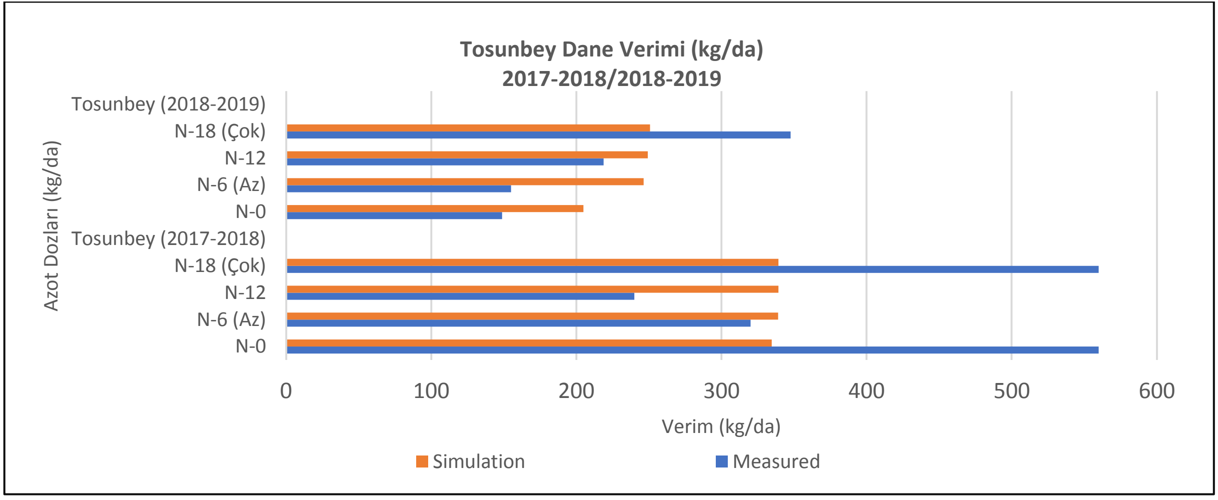

Fig. 7. According to Yield Simulated and Measured Values for Tosunbey (kg/da)

Table 11. Simulated and measured values according to yield values for Tosunbey (kg/da).

Simulated and Measured Yield (kg/da) Values for Tosunbey 2017-2018/ 2018-2019							
		2017-2018			2018-2019		
Applications	**Simulated**	**Measured**	**Hata (%)**	**Simulated**	**Measured**	**Hata (%)**	**Average Error (%)**
N0	**334.6**	**560.0**	**-67.36**	**204.9**	**148.8**	**+27.37**	**-47.36**
N6	**339.1**	**320.0**	**+5.63**	**246.4**	**155.0**	**+37.09**	**+21.36**
N12	**339.2**	**240.0**	**+29.24**	**249.3**	**218.8**	**+12.37**	**+20.80**
N18	**339.2**	**560.0**	**-65.09**	**250.7**	**347.7**	**-38.69**	**-51.89**
Average Estimate (%)	**338.0**	**420.0**	**-24.39**	**237.8**	**217.6**	**+38.14**	**-57.09**

Table 12. Simulation evaluation results for Bayraktar variety (2017-2018).

Çeşit/Gelişme Dönemi	**Gübre Uygulama Dozu (N)**	**Plant Height (cm.)**		**Maksimum Yaprak Alan İndeksi (Max-LAI)**		**Harvest Index (% HI)**	
		Measured	**Simulated**	**Measured**	**Simulated**	**Measured**	**Simulated**
Bayraktar (2017-2018)	**N-0**	**45.25**	**45.12**	**2.21**	**2.82**	**0.249**	**0.349**
	N-6 (Less)	**44.375**	**45.12**	**1.99**	**3.29**	**0.277**	**0.278**
	N-12	**47.0**	**45.12**	**2.54**	**3.38**	**0.308**	**0.245**
	N-18 (More)	**43.5**	**45.12**	**2.35**	**3.42**	**0.294**	**0.246**

Accuracy (Validation) CERES-Model

RMSE	**8.450**	**1.670**	**0.064**
d-State	**0.985**	**0.730**	**0.005**
r-square (r^2)	**0.962**	**0.561**	**0.930**
Uyum Derecesi	**Çok İyi**	**Çok İyi**	**Çok İyi**

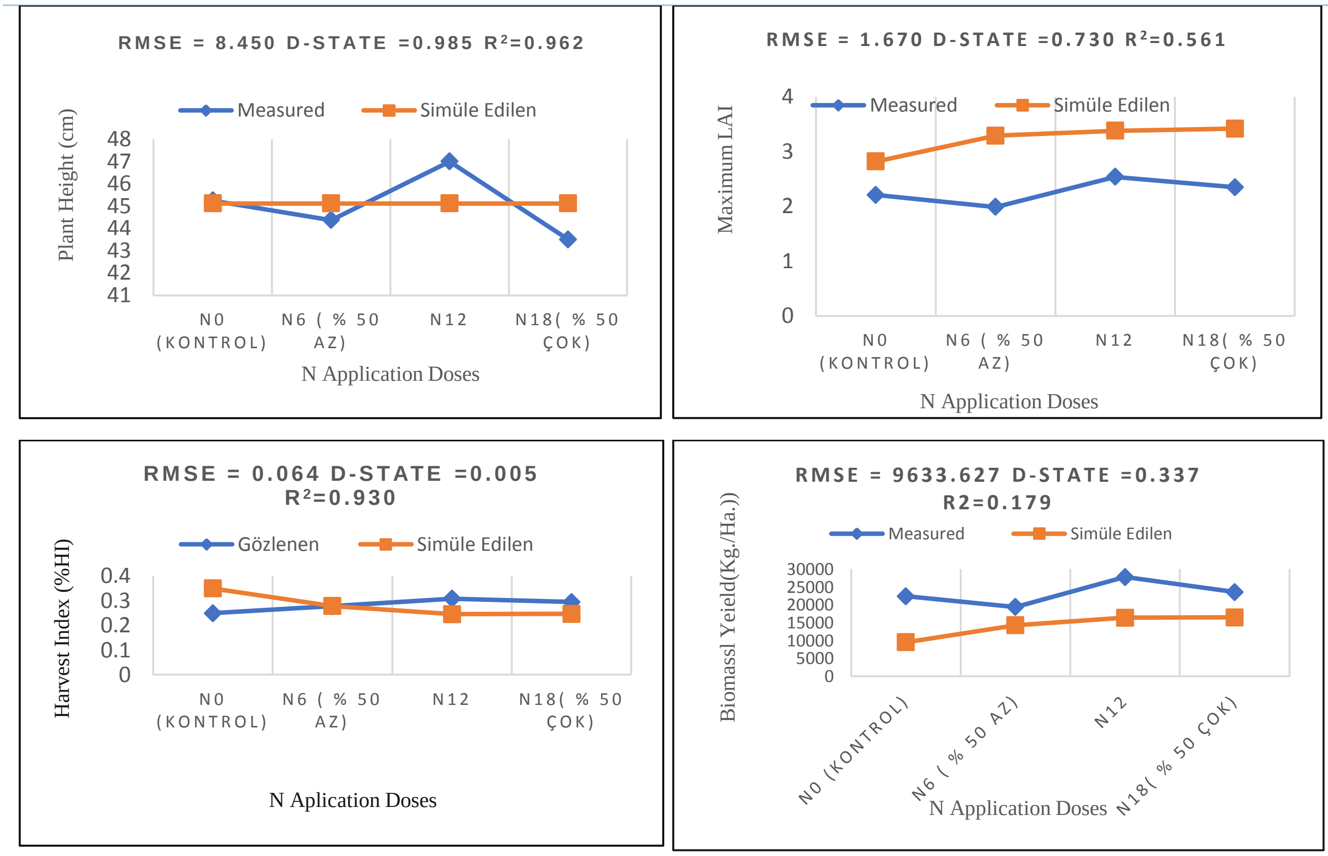

Fig. 8. Performance Evaluation of Simulation Results of Phenological Parameters in Bayraktar 2017-2018 Period (Model Verification-Cross-Validation)

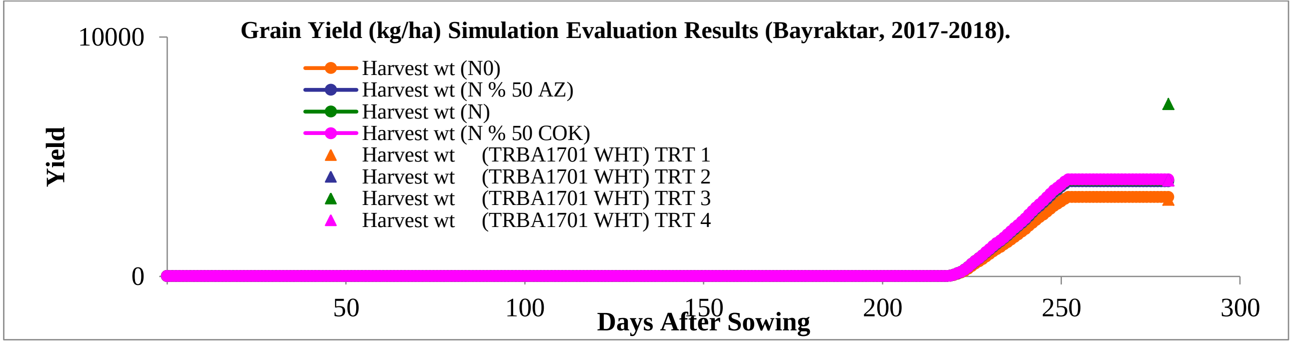

Fig. 9. Grain Yield (kg/ha) Simulation Evaluation Results (Bayraktar, 2017-2018).

Table 13. Measured and simulated yield values and estimated harvest days at different nitrogen application doses (Bayraktar, 2017-2018)

Nitrogen Application Doses	**Measured Yield Data (kg/da)**	**Simulation Yield Data (kg/da)**	**Estimated Harvest Days**
N_0 (Gübresiz)	320 (Harvest wt (N0)	308.0 (TRBA1701 WHT) TRT1	246
N_6 (% 50 Azaltılmış)	400 (Harvest wt (N% 50 Az)	363.9 (TRBA1701 WHT) TRT2	251
N_{12} (Optimum)	720 (Harvest-Opt.)	369.8 (TRBA1701 WHT) TRT3	280
N_{18} (% 50 Artırılmış)	400 (Harvest wt (N% 50 Çok)	372.0 (TRBA1701 WHT) TRT4	254

Considering the 2017-2018 grain yield results, it was measured that the simulation results obtained from the model under different fertilizer dose applications did not provide the desired consistency with the measured data (Fig. 9). Especially at the N_{12} nitrogen application dose, Haymana showed a yield well above its potential in arid conditions (7200 kg./ha). The biggest factor in this was that the precipitation in the 2017-2018 development period followed a course close to the ideal. Bayraktar variety received a lot of precipitation especially in May, which caused this variety to exceed its yield potential (Table 13).

Table 14. Bayraktar 2017-2018 Yield Estimation Statistical Analysis Results (N_{12} Dose Neglected)

Yield (kg/da) Assessment (Bayraktar 2017-2018)

Application	**Observed**	**Simulated**	**R² (Ort.)**	**Relative Error (%)**	**Mean Diff. (kg/ha)**	**Mean Abs.**	**RMSE**	**Used.Obs**
N_0	**320.0**	**338.7**	**0.8921**	**5.84375**	**187**	**187**	**187**	**1**
N_6 (%50 less)	**400.0**	**380.7**		**-4.825**	**-193**	**193**	**193**	**1**
N_{18} (%50 more)	**400.0**	**401.8**		**0.45**	**18**	**18**	**18**	**1**

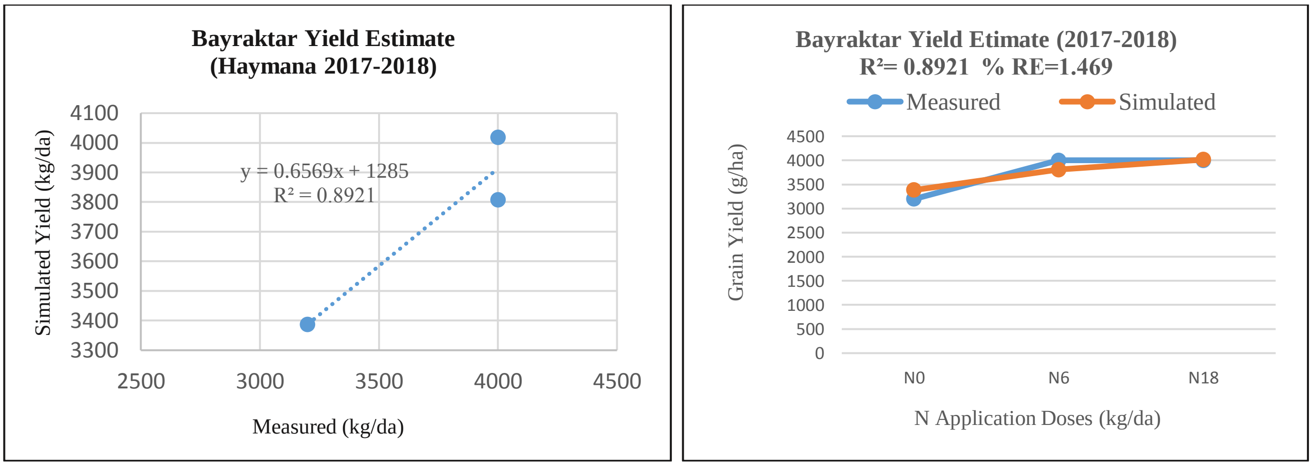

Fig. 10. Yield Estimation Simulation Results for Bayraktar Variety (Haymana 2017-2018).

Table 15. Bayraktar 2018-2019 simulation evaluation results.

Variety/ Development Period	**Fertilizer Application Doses (N)**	**Plant Height (cm.)**		**Maximum Leaf Area Index (Max-LAI)**		**Harvest İndex (HI)**	
		Measured	**Simulated**	**Measured**	**Simulated**	**Measured**	**Simulated**
Bayraktar (2018-2019)	**N-0**	**56.88**	**54.82**	**1.92**	**1.45**	**0.035**	**0.451**
	N-6 (Az)	**57.62**	**54.82**	**1.76**	**1.76**	**0.124**	**0.441**
	N-12	**59.5**	**54.82**	**1.96**	**1.75**	**0.223**	**0.438**
	N-18 (Çok)	**57**	**54.82**	**1.71**	**1.75**	**0.227**	**0.436**
Validation CERES-Model							
RMSE		**12.012**		**0.986**		**0.301**	
d-State		**0.975**		**0.850**		**0.313**	
r-square (r^2)		**0.976**		**0.537**		**0.925**	
Degree of Compliance		**Good**		**Very Good**		**Very Good**	

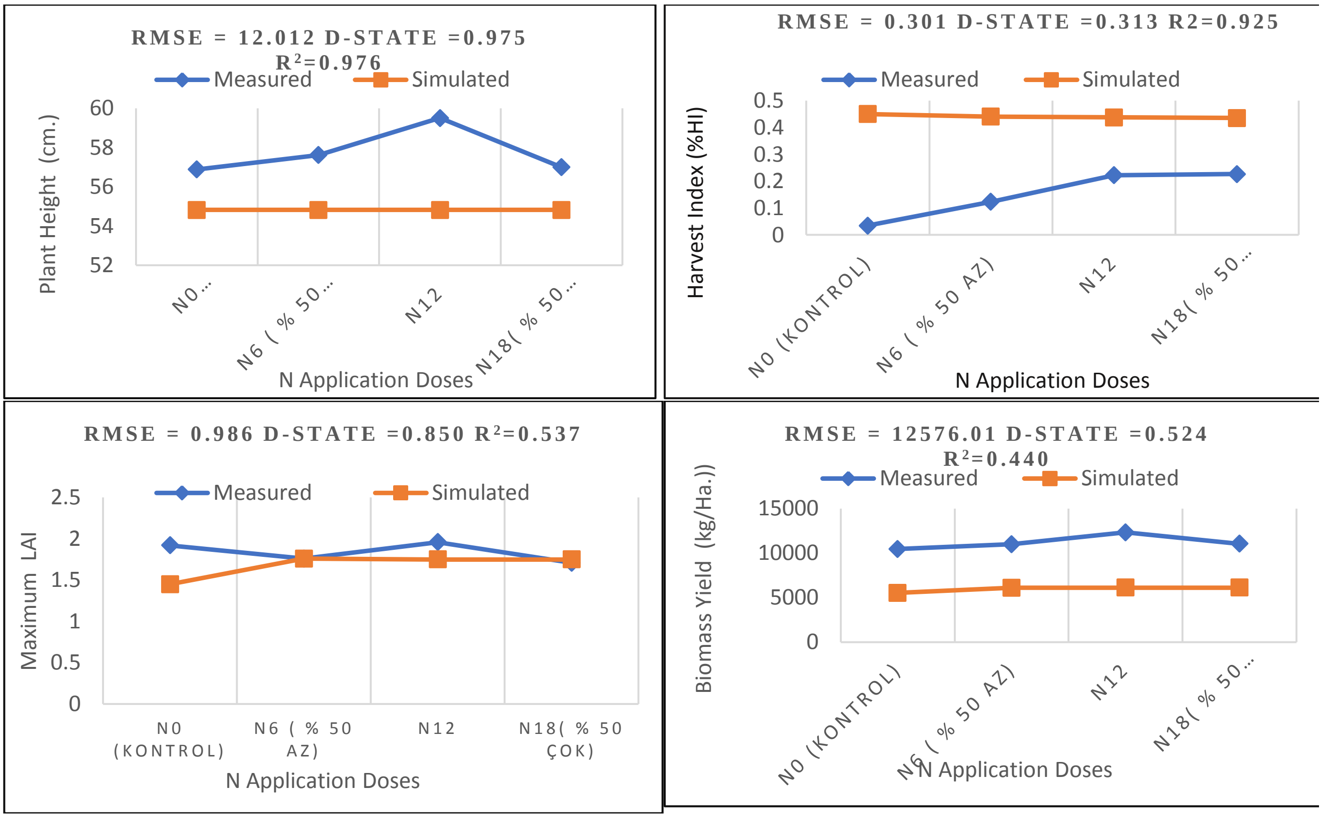

Fig. 11. In Bayraktar variety, performance evaluation of simulation results of phenological parameters for 2018-2019 period (Validation of the Model -CrossValidation).

The % soil moisture values obtained from the gravimetric soil analyzes performed on the soil samples taken from different depths (0-30, 30-60, 60-90 cm.) at different times of the development period showed low values. Regular and excessive rains in the precipitation regime in May caused the Bayraktar variety to have a higher yield potential than expected. While simulation application index values obtained from other nitrogen application doses (N_0, N_6, N_{18}) gave good results, N_{12} application dose did not give a positive result in terms of yield estimation in general. This fluctuation in the grain yield estimation in the simulation led to great differences between the index values used in the accuracy estimation of the model that emerged in the tillering (RMSE= 1526.0) and the above-ground biomass estimation (RMSE= 9633.627). Therefore, while performing the simulation for the 2017-2018 period, the N_{12} dose was neglected and the yield estimation was evaluated (Table 14) (Figure 10) (Table 15).

In the 2018-2019 development period, Bayraktar variety could not show its real yield potential due to the intense rye pressure of the parcel and flood damages in the same N fertilizer dose applications. Despite this, the highest yield was obtained at the N_{12} dose (3305 kg/ha.).

Discusssion

The results of the research showed that the simulation results of the DSSAT CSM CERES Wheat model gave good results, provided that the plant parameters required for the model study were taken correctly and on time. The model was run at different fertilizer application doses, and the simulation results obtained accordingly were compared with the observed values. The DSSAT CSM CERES Wheat model was run and calibrated for winter wheat using phenological parameters obtained under Haymana conditions. Although the simulation results obtained are valid for the Haymana location, they do not mean that it can be used in all Central Anatolian arid conditions. Only the results obtained give a chance to make a prediction about the regional yield estimation. In order to give for the model healthy results and make good predictions, it should be tested in more locations, at different nitrogen application doses, on more local varieties, and the plant genetic coefficients related to these should be determined and calibrated for each variety. In the study, the DSSAT model showed higher simulation values and gave more accurate results in the first year (2017-2018) yield estimation and plant phenological parameters (plant height, leaf area index, harvest index) for Bayraktar cultivar. In the second year (2018-2019), significant differences were seen in the simulation values in the estimation of yield due to heavy rye pressure invading the wheat and flooding in the trial area. On the other hand, important estimation results were obtained in the simulation values of plant parameters. The obtained results can be increased in accuracy and calibrated by establishing more trials and using local varieties. The DSSAT model can be used in the future to determine the optimum planting date and local varieties to be used, by using retrospective and current climate data, and to predict yield losses that may occur. As the product parameters can be predicted according to the regions, the yield potential of local wheat varieties can be determined in advance by taking into account the soil type and temperature-precipitation situation in the areas where no cultivation is made. The DSSAT model plays an important role in shaping the national agricultural policy in the future by examining the effects of climate on the crop. Product simulation models are important in making management plans in advance.

Conclusions

Genetic coefficients were obtained from the DSSAT v.4.7.5 CSM- CERES for the parameters of bread wheat Bayraktar variety, during 2017-2018 and 2018-2019 periods. **(**Table 16). For the Winter Bayraktar variety; The PHINT (Growing degree days) coefficient was determined as 199 (Saseendran et.al., 2004). This coefficient was calculated as 76 GDD in simulation studies in semi-arid areas in the state of Colorado in the USA.Since the experiment area is located in the semi-arid climate zone of İkizce village of Haymana district, the PHINT coefficient being 199, especially for the location and variety, was due to the difference in the geographical and genotype of the plant. Vernelization coefficient (P1V): Although there is a value of 60 d for all cultivars, this value may vary depending on the location and the difference in flowering time (Ritchie (1991). In experiment, this value was found to be 72.4 for Bayraktar in yield estimation from the model. Photoperiod Coefficient (P1D), varies between 43% and 58%. Godwin et.al.(1989), suggested that this value should be taken as 60% in the northern regions of America and 70% in western and eastern Europe for winter wheat. The ripening date, which is effective in the vernelization coefficient (P1V), plays an important role in determining this coefficient. In the study, this value was calculated as 132.6 from the model for the Bayraktar variety in the Haymana-İkizce experimental area. Grain Filling Period (P5) varies between 221-340 GDD depending on the variety. In the simulation study conducted in eastern Europe, Godwin et.al. (1989) found this value to be 550 GDD. In the study, this value for Bayraktar was calculated as 467.1 GDD from the model. Virgo Coefficient (G1) : In the simulation study, Godwin et.al. (1989) suggested this value as a constant 25 kg-^{1} for North America and 27.5 kg-^{1} for Europe. In later studies, this value was calculated in the range of 15-50 kg-^{1}. In the study, this value for Bayraktar was calculated as 17.5 kg-1 from the model. Standard Spike Weight (G2): In the simulation study, Godwin et.al. (1989) suggested this value as a fixed 40 mg for North America and Western Europe for winter wheat varieties. It is recommended that this value be between 33-49 mg. In the field trial, this value was calculated as. 30.9 mg from the model. Standard Grain Weight (G3) : The optimum grain weight of all cultivars in a single sibling was determined as 2.9 gr. Godwin et.al. (1989) suggested this value as 1.5-2.0 g. In later studies, Yang et al. (2006) reported this value in the range of 1.5-2.9 gr. In the field trial, this value for Bayraktar was calculated as. 4.34 gr.

Table 16. Genetic Coefficients calculated at different nitrogen application doses for Bayraktar and Tosunbey Cultivars (Haymana-İkizce 2017-2018/2018-2019).

Period	**Varieties**	**Latitude Longtitude**	**Location**	**Climate Zone**	**Correlation Coefficient**							
					Nitrogen Doses	**PIV (days)**	**P1D**	**P5 (ºC.d**	**G1 (#/g)**	**G2 (mg)**	**G3 (gdwt)**	**PHINT (°C.d)**
2017-2018 2018-2019	Bayraktar	39^{0} $36^{'}$ 53"N, 32^{0} $40^{'}$ 45" E;sağ üst 39^{0} $36^{'}$ 59"N, 32^{0} $40^{'}$ 47" E Sol alt	East-Mediterrain	Semi-Arid Climate	No,N6,N12,N18	72.4	132.6	467.1	17.5	30.9	4.34	199.0
2017-2018 2018-2019	Tosunbey				No,N6, N12,N18	50.7	126.6	463.6	24.7	31.7	1.86	298.4

Table 17. Number of Days to Flowering (Bayraktar 2017-2018 / 2018-2019).

Nitrogen Application Doses	**Number of Days to Flowering (2017-2018)**			**Number of Days to Flowering (2018-2019)**		
	Sim.	**Obs.**	**Difference (gün)**	**Sim.**	**Obs.**	**Difference (gün)**
N0	216	216	0	223	214	9
N6	216	216	0	223	214	9
N12	216	216	0	223	214	9
N18	216	216	0	223	214	9

Table 18. Maturation Days (Bayraktar 2017-2018 / 2018-2019).

Nitrogen Application Doses	Olgunlaşma Gün Sayısı (2017-2018)			Olgunlaşma Gün Sayısı (2018-2019)		
	Sim.	Obs.	Difference (gün)	Sim.	Obs.	Difference (gün)
N0	252	252	0	257	254	3
N6	252	252	0	257	254	3
N12	252	252	0	257	254	3
N18	252	252	0	257	254	3

Plant genetic coefficients obtained for Tosunbey for 2017-2018 and 2018-2019 periods Vernelization coefficient (P1V) 50.7, Photoperiod Coefficient (P1D) coefficient 126.6, Grain filling period (P5) 463.6 GDD, Spike Number Coefficient (G1) 24.7 k g- 1, Standard Head Weight (G2) 31.7 mg, Standard Grain Weight (G3) 1.86 gr. and the PHINT (Growing degree days) coefficient was determined as 298.4 (Table 18). P1V : Vernelization Coefficient 60 (For Winter Genotypes) P1D : % decrease in growth rate in the GDD process (in a photoperiod shorter than 10 hours) between 54-58% is desired. P5: Grain Filling Period (between 221-340 days is desired). G1: The number of spikes per unit canopy in Flowering Weight (Number/m^2) (It is desired to be between 15-50 kg-^{1}). G2: Standard spike size (Weight) (mg.) under optimum conditions (33-49 mg is desired).G3: Standard Grain Weight (gr) was calculated from a single sibling during maturity (1.5-2.9 gr is desired). PHINT: Days in Development (GDD) (requires 95 days).

It was were used for 2-year field trial data to test the prediction capacity of the DSSAT Model in wheat under Haymana conditions (2017-2018, 2018-2019). For the calibration of the model, the grain yield and Leaf area index (LAI) data were used obtained in the first year wheat development stage. The model was run at different nitrogen application doses (0, 6, 12, 18 kg/da) to reveal the yield prediction potential of wheat under semi-arid conditions. Performance of DSSAT model verified after calibration. Phenological plant parameters were used in the validation process. These phenological parameters are flowering date, ripening date, harvest yield and plant yield parameters (plant height, LAI, biomass, etc.) (Hunt et al., 1993). In general, in Bayraktar cultivar, the model gave good predictive results in product development and grain yield. Especially, significant closeness was observed between the observed and simulated values between the number of days calculated according to flowering, maturation and total water level during 2017-2018 and 2018-2019 periods.While there was no difference between the estimated and simulated values between the number of flowering and ripening days in the first year (2017-2018) for Bayraktar (Table 16), the number of flowering days in the second year (2018-2019) was 9 days, and there was a 3-day difference in the number of maturation days (Table 17). There was a difference of 11 days in the first year and 12 days in the second year in the simulation values calculated according to the soil water level (Table 18).

Yield parameters obtained from two-year simulation results (2017-2018/2018-2019) R^2= 0.892, % RE= 3.7 Plant height R^2= 0.958, dstat =0.982, RMSE= 9.115 R^2= 0.561 for leaf area index (LAI), dstat = 0.730, RMSE= 1.387, Harvest Index R^2=0.930, dstat =0.005, RMSE=0.064, total water level R^2=0.635, dstat =0.875, RMSE=39.924. From these results, it was concluded that plant growth and yield could be simulated effectively from the trial area. The calibration and testing of the model was achieved by using the results obtained from two years of data and two local cultivars (Bayraktar, Tosunbey). The average yield obtained from different nitrogen dose applications (N_0,N_6,N_{18}) was found to be 373.73 kg/da (N_{12} dose was neglected). When evaluated in terms of yield simulation results for Bayraktar and Tosunbey varieties of winter wheat, DSSAT CERES Wheat model showed significant results in line with the observed data in terms of prediction. The model was calibrated with plant parameters obtained from local field trials in order to reveal the genetic coefficients specific to the variety. When the two-year data (2017-2018/2018-2019) are evaluated together in terms of the performance of the model, it has been observed that the differences between the observed values and the predicted values are very small, so they are within acceptable limits. In order to increase the model performance, it is necessary to set up more trials for different locations, run the model for different cultural winter wheat varieties and obtain genetic coefficients.

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