Yield Predicationby DSSAT model of wheat crop: A review

ABSTRACT

The DSSAT model predicts crop productivity under different crop management scenarios and fluctuating climate circumstances, necessitating the identification of a crop cultivar's genetic coefficient. The precision with which various parameters are calibrated and validated is essential to the effective application of crop models. The model was calibrated using the data on irrigation and nitrogen's impact on wheat yield, and it was validated using the date of sowing. The closer estimation of crop growth time, grain yields, and biomass yields was demonstrated by the model findings. The percentage error discrepancy between the simulated and actual wheat variety grain yields was 8.70% to 10.98%, respectively. There is a substantial correlation with a higher R2 value between the simulated and observed grain yields and crop duration during both the calibration and validation processes.

Keywords:DSSAT Model, Wheat, Yield,Simulated, Validation

INTRODUCTION

"Yield estimation of wheat crop by Decision Support System for Agro technology Transfer (DSSAT) is a package of 16 different crop growth models that access soil and weather data files along with management files of specific crops to predict crop growth and yield" (*Jones et al., 2003).*For more than 20 years, more than 100 countries have utilised the well-liked crop model DSSAT [6]. This software package for microcomputers offers meteorological and soil data, programmes for assessing management approaches, and a shell programme for the interface of crop-soil simulation models. More than 40 crop growth models are included in DSSAT. Among them, the most popular crop simulation model is CERES-Wheat. There is very little agricultural modelling research, particularly DSSAT on various crops, in Bangladesh. The DSSAT cultivar database does not provide cultivar coefficients for common wheat varieties in Bangladesh (Choudhury et al., 2018).

By assisting the model in producing more accurate forecasts and predicting weather unpredictability, the DSSAT creates future weather scenarios (Jame and Cutforth, 1996). "For a variety of applications, including the prediction of crop duration and growth stages, grain yield simulation, the impact of planting dates on crop yield and water requirement, water scheduling, and nitrogen management, the CERES-Wheat crop simulation model has been extensively tested and validated under a variety of agroclimatic conditions in different states of India" (Nain et al. 2004). Utilising edaphic, biotic, and agronomic aspects, crop growth simulation models are used to examine how different climatic parameters affect crop growth and yield. Many studies have used a dynamic modelling framework to produce an integrated assessment of climate change and variability on regional and global supplies and demand (Adams et al., 1995, Alexandrov and Hoogenboom, 2000). Rosenweig and Parr (1994), Friedrich and Parr (1994).

Validation of DSSAT model:

According to Baxla et al., "in all validation years, the hind cast wheat yields for the majority of the districts fall within the acceptable error limit (10%); however, in the years 2011–12 for the Central Plain zone (Kanpur), 2012–13 for the Buldelkhand zone (Jhansi), and 2013–14 for the Eastern Plain zone (Faizabad), the prediction was slightly higher". The variability in wheat crop productivity caused by temperature increases during the booting or grain filling stages can be easily observed in the results of simulations. The model that was validated for the previous year's grain yield, version 3, displayed a 9–10% variance. This can be improved by fine-tuning the genetic coefficient and other district-level input data.

Impact of climate change on wheat yield estimation:

Aarya *et al*., (2020) examine that, "climate change simulations with GCM projections under IMPs and elevated CO2 effect showed wheat yield remained unchanged (− 0.4 to + 9%) for all three genotypes. They propose that the IMPs and elevated CO2 were able to reduce the 11 negative effect of elevated Temp. on wheat yield as Temp. Stress did not go beyond optimal T range for wheat. Overall, climate change may not reduce wheat production in the climate of the location of study in the near future, mid century, or end century".Daloz *et al.,* (2021) reported that due to climate change, Temperature and precipitation variations, as well as four IGP sites—Punjab, Haryana, Uttar Pradesh, and Bihar—have an impact on wheat yields. The findings demonstrated that the direct effects of climate change result in losses in wheat production ranging from −1% to −8% due to variations in temperature and precipitation.Results determined by Pal *et al.,* (2015) that CERES-Wheat model used a tool to support decision-making for wheat production in Tarai region of Uttarakhand. CERES-Wheat model was used to simulate responses of two wheat cultivars under different growing environments.

"An experiment was conducted for the period of 2007-08 and 2008-09, on three sowing dates viz. 20th November, 15th December, and 09th January with two varieties *viz.*, PBW-343 and WH-542". [22] Results showed that model outputs was good agreement with observed values in terms of phonological, biomass accumulation and grain yields with crop sown in 20th November than other sowings of crop. Whereas, PBW-343 variety showed close good agreements between simulated and observed outcomes in all sowing dates.Junfang *et al.*, (2017) concluded that "the relationships between climate changes with crop production will help tactical decision for future agricultural adaptation in China using Agricultural Production Systems Simulator (APSIM) model. Results showed that general yield reduction of spring wheat in return to the evident of climate warming from 1981 to 2014, with an standard of 3564 kg·ha-1. The regional differences in yields were found significant. Western region of China had founded that maximum yield potential of spring wheat. Whereas, the minimum potential yield was found in the middle region of the country. They observed the air temperature and soil surface temperature were the supreme climatic factors that shape the key phenophases of spring wheat at Inner Mongolia".

According to Evers et al. (2010), "the ratio of the plants' assimilate supply to demand determines how many tiller buds sprout. Photosynthesis at the organ level, biomass production, and bus growth were satisfactorily simulated. However, further mechanistic work is required to represent other important plant physiological processes, such as nitrogen uptake and distribution, tiller mortality, and leaf senescence, in order to improve crop simulation outcomes. However, the work that has been described here represents a major advancement towards a mechanistic functional structural plant model that integrates important plant activities with plant architecture".

Temperature effect on wheat yield:

The CERES-Wheat model, which was used to simulate grain yield and oversimulation, shown a decrease in temperature model sensitivity following anthesis, observed by Hussain et al. (2018). The days to anthesis and maturity in the CERES-Wheat simulation did not demonstrate the impact of high temperatures on grain size and filling duration as seen in the field during the grain filling stage. CERES-Wheat also underreports the impacts of heat on scheduled laying on grain filling length, according to Liu et al. (2016). According to Rezzoug et al. (2008), the model calibration resulted in root mean squared errors (RMSE) of 9.5 and 1.8 days for anthesis and maturity, respectively. The model testing resulted in RMSEs of 4.4 and 3.5 days, respectively. In terms of testing and calibration, the final grain yield's RMSE was 0.7 t ha -1. This study demonstrated that the growth and yields of Algerian wheat genotypes could be predicted using DSSAT. Consequently, it is necessary to contrast various crop management techniques in a wheat-growing region.The DSSAT (v4.6) crop model for wheat production in Bangladesh was found to be validated by Choudhury et al. (2018). DSSAT was used to calculate the genetic coefficient of four wheat cultivars (BARI Gom-25, 26, 27, & 28). Model calibration and validation were conducted using experimental data on the effects of irrigation and nitrogen on wheat output, as well as the date of planting. The evaluation of the model yielded closer estimates of biomass yields, 12 grain yields, and crop growth duration.

Between simulated and actual values, the percent error variation in grain yield of wheat types (BARI Gom-25, 26, 27, and 28) was 10.98%, 8.70%, 10.79%, and 8.94%, respectively. Strong relationships with higher R2 values are found between the simulated and observed grain yields and the simulated and observed crop duration during the calibration and validation processes (Table 1, 2, 3).

Table-1: An explanation of the various wheat genetic traits that can be used in a model

Name of parameters	
P1V	Days, optimum vernalizing temperature, required for vernalization
P1D	Photoperiod response (% reduction in rate/10 h drop in pp)
P5	Grain filling (excluding lag) phase duration (oC-d)
G1	Kernel number per unit canopy weight at anthesis (#/g)
G2	Standard kernel size under optimum conditions (mg)
G3	Standard, non-stressed mature tiller weight (incl grain) (g dwt)
PHINT	Interval between successive leaf tip appearances (oC-d)

Table-2: Variations in the genetic coefficient of wheat[22]

Variety	P1V (Days)	P1D (% reduction in rate 10 h -1 drop in pp)	P5 (oC. d)	G1 (#/g)	G2 (mg)	G3 (g dwt)	PHINT (oC. d)
BARI Gom-25	0	92	725	23	46	3.6	70
BARI Gom-26	0	92	730	23	46	3.8	70
BARI Gom-27	0	93	740	24	46	3.9	70
BARI Gom-28	0	96	750	25	47	3.9	70

Table-3: Goodness of fit indicators for various wheat varieties' crop length and grain yield during the 2012–13 calibration period.

Variety	Parameter	Sim.	Obs.	PE (%)	R 2	NRMSE	EF	d
BARI Gom-25	Crop duration	113	111	1.80	0.87	4.04	0.49	0.88
	Grain yield	4931	4443	10.98	0.63	0.98	0.98	0.99
BARI Gom-26	Crop duration	115	113	1.76	0.85	4.19	0.83	0.95
	Grain yield	4937	4542	8.70	0.82	0.52	0.99	0.99
BARI Gom-27	Crop duration	110	107	2.80	0.93	5.29	0.19	0.81
	Grain yield	5278	4764	10.79	0.86	0.55	0.99	0.99
BARI Gom-28	Crop duration	111	107	3.74	0.59	4.44	0.05	0.79
	Grain yield	5608	5148	8.94	0.89	0.18	0.99	0.99

"In order to identify gaps in simulating wheat grain protein concentration and yield for crop model improvement, the study reported a thorough comparison of four widely used wheat simulation models (DSSAT-CERES-Wheat, DSSAT-Nwheat, WheatGrow, and APSIM-Wheat). These models were used to quantify and simulate the responses of wheat grain quality (GPC and GPY) under LTS and HTS at critical growth stages. Two wheat types were subjected to LTS (at the joining and booting stages) and HTS (at the anthesis, grain filling, and combined stress at the anthesis and grain filling stages) throughout four years of environment-controlled phytotron trials. According to Osman et al. (2020), there was a 0.2% to 0.4% increase in GPC and 1.1% to 1.6% increase in GPY for every unit increase in cold degree days (CDD, degree days below 2 °C) at jointing and booting stages and heat degree days (HDD, degree days over 30 °C) at anthesis, grain filling, and combined stress at anthesis and grain filling stages".[22]

Three cultivars were tested in the field across a wide variety of sowing dates by Hussain et al. (2018) in two distinct climatic zones in Punjab, Pakistan: Layyah 13 (arid) and Faisalabad (semi-arid). Temperatures throughout the wheat growth season varied from -0.1°C to 43°C. The broad range of planting dates presented a singular chance to cultivate wheat in a climate with temperature swings between -0.1°C and 43°C. For every wheat cultivar, the least-stressed treatment served as the calibration point for the models CERES-Wheat, Nwheat, CROPSIM-Wheat, and APSIM-Wheat. All things considered, the performance of early, optimal, and late sown wheat was adequately represented by four models; nevertheless, the yields of very late planting dates with high temperatures during grain filling were poorly described. Given the anticipated future increases in growing season temperature, it is imperative to enhance the accuracy of model simulations at the high end of the growth temperature range, as seen by the inadequate yield simulation accuracy for extreme planting dates.

CONCLUSION

wheat yield prediction using the DSSAT model following effective calibration and validation of the model's performance using the temporal course of above-ground biomass, phenology, and harvested grain yield. It is possible to draw the conclusion that the model performs effectively in a variety of growing environments and may thus be applied to studies that analyse the effects of climate change and natural resource management. The model's simulated grain yield indicated a rise in temperature, and after anthesis, the model's sensitivity decreased. High temperatures during the grain filling stage did not have the same influence on grain size and filling length as in the field, according to the CERES-Wheat simulation of days to anthesis and maturity.

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