



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
www.agronomyjournals.com
2025; 8(2): 191-200
Received: 29-11-2024
Accepted: 10-01-2025

Nickey Agrawal
Department of Agricultural
Meteorology, Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

Dr. Harsh Vardhan Puranik
Department of Agricultural
Meteorology, Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

Dr. Gopi Krishna Das
Department of Agricultural
Meteorology, Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

Corresponding Author:
Nickey Agrawal
Department of Agricultural
Meteorology, Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

Calibration and validation of CERES-wheat and APSIM models for different wheat varieties in Raipur district of Chhattisgarh

Nickey Agrawal, Harsh Vardhan Puranik and Gopi Krishna Das

DOI: <https://doi.org/10.33545/2618060X.2025.v8.i2c.2573>

Abstract

Two crop simulation models with CERES-Wheat and APSIM models were calibrated and validated for three wheat varieties (Kanchan, HD2967 and CG1013) under three different sowing dates (D₁: 30th Nov, D₂: 10th Dec, D₃: 20th Dec) in the Raipur district of Chhattisgarh. Experiments were carried out at Research Farm College of Agriculture, Raipur, during the rabi season 2021-22 & 2022-23. Calibration was done by 2021-22 and validation was done by 2022-23 field data. RMSE and Error Percentage were used to evaluate the performance of models. The results indicated that both models could predict growth parameters & yield with reasonable accuracy, as evidenced by low root mean square error (RMSE) values and error percentages. For the CERES-Wheat model RMSE for the anthesis period ranges between 1.2 to 4.0 days and the error percentage was varied between 2.6% to 9.3% across the varieties and sowing dates. The APSIM model showed even lower RMSE values ranging from 0.6 to 2.9 days and error percentage was noticed between 1.3% to 6.8%. The RMSE values of grain yield ranges between 38.7 to 125.3 kg/ha for CERES-Wheat and 49.0 to 139.8 kg/ha for the APSIM model. Models predicted growth parameters & yield accurately with less than 10% of error percentages. So, both the models will be used for climate change studies & natural resource management applications.

Keywords: Calibration and validation, DSSAT, APSIM, wheat varieties, RMSE

Introduction

Wheat (*Triticum aestivum* L.) is a staple food crop of global significance, cultivated in temperate, tropical and subtropical regions. Optimal wheat growth requires a combination of cool and moist conditions during the early stages of growth, followed by dry and warm weather during grain filling and maturation. Ideal germination occurs within a temperature range of 20 °C to 25 °C, while vegetative growth thrives between 16 °C and 22 °C. During grain development, a mean maximum temperature of approximately 25 °C for 4-5 weeks is beneficial. Wheat can grow well in areas with annual rainfall between 250 mm and 1800 mm. Winter wheat benefits from low temperatures during early growth stages and high temperatures during later stages of development.

India plays a crucial role in global wheat production, contributing 12.5% of total output over the past two decades, with a cumulative production of 1.8 billion tonnes. As the world's second most populous country, India was projected to produce 105 million tonnes of wheat in the 2022-23 season while consuming approximately 104.5 million tonnes (FAO, 2023) [8]. Wheat is cultivated across 26.69 million hectares, with an average yield of 2,703 kg per hectare, accounting for nearly 35.5% of the nation's total food grain production.

Temperature is a critical weather parameter impacting wheat yields. Variations in temperature influence grain yield primarily through their effects on phenological development. Winter wheat is particularly vulnerable to high temperatures during reproductive stages. Research has shown that increased night-time temperatures during the reproductive phase can significantly reduce grain filling rates and yield (Al-Khatib and Paulsen, 1984; Zhao *et al.*, 2008; Talukder *et al.*, 2013) [4, 16, 15]. A 1 °C rise in air temperature can shorten the flowering period by five days (Saini and Nanda, 1987) [13]. In Central India, where temperature fluctuations are significant. Wheat productivity is sensitive to temperature changes. For example, a 1 °C increase in temperature

during the growing season may not affect productivity in North India but can significantly reduce potential grain yields in Central India. Thus, selecting the optimal sowing date is crucial for ensuring good germination and higher yields. Although dwarf wheat varieties are photoperiod-insensitive and adaptable to both early and late sowing, extreme sowing times can reduce tillering and result in poor seed quality due to high temperatures (Aggarwal and Sinha, 1993) ^[1].

Crop simulation models (CSMs) are vital tools for assessing the impact of climate change on food production. These models, such as APSIM (Agricultural Production Systems Simulator) and DSSAT (Decision Support System for Agrotechnology Transfer), simulate crop growth and yield based on various climatic, soil and management scenarios. CSMs are based on scientific principles and provide a means to estimate crop performance under different conditions (Leffelaar, 1993) ^[11]. APSIM-Wheat and DSSAT models have been extensively used to simulate the effects of climate change on wheat production in different regions, including the Indian subcontinent (Rosenzweig and Iglesias, 1998; Lal *et al.*, 1998) ^[12, 10].

The APSIM-Wheat model integrates several modules to simulate crop growth, soil processes and management practices. It requires inputs such as weather, soil and crop data and responds to climate, soil water supply and nitrogen availability. The DSSAT model, initially developed by the IBSNAT project, combines databases and programs to simulate multi-year outcomes of crop management strategies. It allows users to evaluate various scenarios and management options quickly. Calibrating and validating of models under local conditions is crucial for accurate predictions. Calibration involves adjusting the model parameters to match historical data, while validation compares model predictions with results from independent experiments.

In Chhattisgarh, wheat is grown on 245.36 thousand hectares with a production of 317.25 thousand kg and an average productivity of 1293 kg/ha during 2022-2023 (Anonymous, 2024) ^[5]. Wheat cultivation is predominantly under irrigated conditions in rice-based cropping systems. Delays in wheat sowing due to the late harvest of rice varieties result in high temperatures during the grain-filling and ripening phases, contributing to reduced productivity. Additionally, Chhattisgarh faces the threat of climate change, which may exacerbate the challenges faced by wheat production. Previous studies have shown significant variability in climate impacts across the state, affecting agricultural productivity (Sastri, 2010) ^[14].

This research aims to calibrate and validate the CERES-Wheat and APSIM models for wheat varieties in the Raipur district of Chhattisgarh to better understand and address the impact of local and climate-induced changes on wheat production.

Materials and Methods

1. Location of Experimental site

The experiment was conducted at the experimental farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, which is located at the latitude of 21.16' N, longitudes 81.36'E and altitude of 289.5 m above mean sea level. The experiment was conducted on the wheat crop during the *Rabi* seasons of 2021-22 and 2022-23 with three data of sowing (*i.e.*, D₁: 30 November, D₂: 10 December, D₃: 20 December) and three wheat varieties (V1: Kanchan, V2: HD-2967 and V3: CG-1013) under factorial RBD experiment along 3 replications.

2. Database

a. Weather Data

Daily weather data was collected from the Agromet observatory, Department of Agricultural Meteorology, COA, IGKV, Raipur for the year (2021-2022 to 2022-2023). Different weather parameters *i.e.*, Maximum and Minimum Temperature (°C), Rainfall (mm) and Solar Radiation (WM²) of daily weather data were used in both the crop simulation models.

b. Soil data

Physical and chemical properties of soil were used in simulation which given by New Delhi under GKMS Project. Soil classification, colour, slope, permeability and drainage class were the required soil data. The soil profile data included upper and lower horizon depths (cm), percentage sand, silt and clay content, bulk density at (1/3 bar), organic carbon, pH in water, aluminium saturation and root abundance information.

c. Genetic coefficients

Using experimental data from 9 treatments across two factors (sowing dates: 30th November, 10th December and 20th December), cultivar-specific genetic coefficients for wheat varieties Kanchan, HD-2967 and CG-1013 were developed (Table 1 and 2). The crop data sets, including date of sowing, emergence, anthesis, physiological maturity, biomass, yield and yield-attributing characters. The DSSAT and APSIM models were instrumental in accurately calibrating these coefficients, ensuring they reflect the unique growth patterns and environmental responses of each wheat variety under different sowing conditions. This iterative calibration process enhances the predictive accuracy of both models, enabling more precise simulations of wheat growth and yield outcomes across various environments.

Table 1: Genetic coefficients of different wheat varieties used in the DSSAT model:

Name of parameters	Definition	Kanchan	HD2967	CG1013
P1V	Days, optimum vernalizing temperature, required for vernalization.	17.25	16.00	17.55
P1D	Photoperiod response (% reduction in rate/10 h drop in pp).	22.30	27.00	17.20
P5	Grain filling (excluding lag) phase duration.	805.20	998.00	798.90
G1	Kernel number per unit canopy weight at anthesis.	12.68	19.00	16.25
G2	Standard kernel size under optimum conditions (mg).	28.28	16.40	23.55
G3	Standard, non-stressed mature tiller wt. (including grain) (g dwt)	3.00	1.30	1.48
PHINT	Interval between successive leaf tip appearances.	60.00	60.00	60.00

Table 2: Genetic coefficients of different wheat varieties used in the APSIM model:

Parameters or variables	Acronym Name	Value Kanchan	Value HD2967	Value CG1013	Units
Phenology					
Emergence: end of juvenile	TT_EMERGENCE_UNITS	883.8	924.8	863.8	°C days
End of juvenile: floral initiation	TT_END_OF_JUVENILE_UNITS	50	54	50	°C days
Floral initiation: flowering	TT_FLORAL_INITIATION_UNITS	554.8	606.4	568.3	°C days
Flowering: start grain filling	TT_FLOWERING_UNITS	120.0	155.0	120.0	°C days
Start grain filling: end grain	TT_START_GRAIN_FILL_UNITS	411.5	510.7	437.6	°C days
End grain: maturity	TT_END_GRAIN_TO_MATURITY	50	50	50	°C days
Maturity: harvest ripe	TT_MATURITY_TO_RIPE	1	1	1	°C days
Genetic					
Potential grain growth rate during grain filling	POTENTIAL_GRAIN_FILLING_RATE	0.0025	0.002	0.002	g grain ⁻¹ day ⁻¹
Potential grain growth flowering to grain filling	POTENTIAL_GRAIN_GROWTH_RATE	0.001	0.001	0.001	g grain ⁻¹ day ⁻¹
	MAX_GRAIN_SIZE	0.032	0.025	0.032	
Leaf development	PHYLLOCRON	105	105	105	
Vernalization sensitivity	VERN_SENS	1.7	1.67	1.6	
Photoperiod sensitivity	PHOTO_SENS	3.0	3.2	3.1	

d. Calibration and validation

Observed data of 2021-22 was used for calibration and data of 2022-23 was used in validation of both models.

3. Statistical analysis

a. Root Mean Square Error (RMSE)

Statistical analyses of the degree of coincidence between simulated and observed values were done by using Root Mean Square Error (RMSE). The RMSE has been widely used as a criterion for model evaluation. RMSE is calculated by:

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (E_i - M_i)^2}{n}}$$

Normalized RMSE calculates the relative change (mean value, M) of predicted (E_i) against measured (M_i) data. The model result is considered excellent when the nRMSE is less than 10%, considered good if the nRMSE is 10-20%, fair if the nRMSE is 20-30% and poor if the nRMSE >30% (Jamieson *et al.*, 1991, Bannayan and Hoogenboom 2009) [9, 6].

$$nRMSE = \sqrt{\frac{\sum_{i=1}^n (E_i - M_i)^2}{n}} \times \frac{100}{M}$$

3.2 Deviation or error %

Besides the above test criteria, the error % was also calculated in different treatments under study to express the deviation more scientifically.

$$\text{Error \%} = \left[\frac{(\text{Simulated} - \text{Observed})}{\text{Observed}} \right] \times 100$$

Results and Discussion

1. Calibration & validation of (DSSAT 4.8.2.0) and (APSIM 7.10) models for different varieties of wheat crop

Model calibration involves refining model variables to minimize errors and achieve simulated outputs that closely align with observed data. Since simulated values do not always perfectly match observed data, slight parameter adjustments are necessary. In this study, cultivar-specific genetic coefficients for three wheat cultivars (Kanchan, HD-2967, and CG-1013) were determined through repeated iterations until the simulated phenology, growth, and yield closely matched the observed

values. The model was calibrated using experimental data from the 2021-22 growing season, focusing on phenology (days to anthesis and maturity) and grain yield. To assess model performance, various statistical metrics, including Root Mean Square Error (RMSE), coefficient of determination (R²), and normalized RMSE, were used.

A. Calibration of DSSAT model for different varieties of wheat crop

Table 1 showed the deviation between simulated and observed values of anthesis, maturity period and grain yield of different varieties of wheat crop.

Days taken to Anthesis

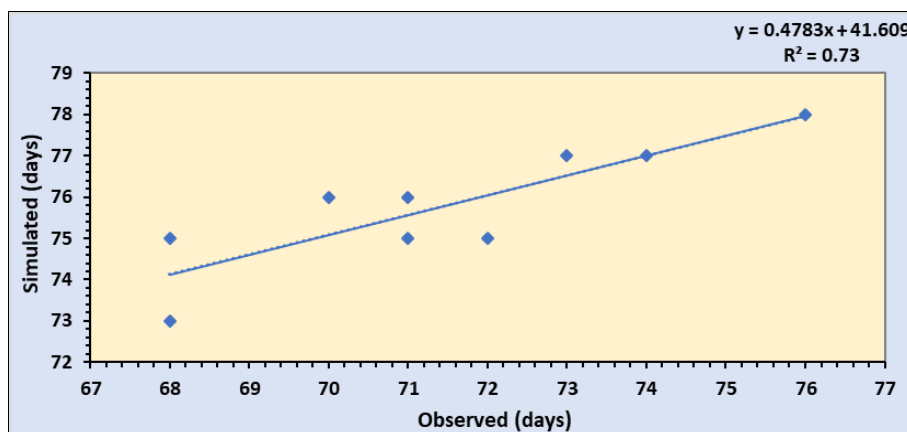
Fig. 1(a) revealed that the deviation between simulated and observed duration of anthesis were recorded +4 to +7 days, +2 to +5 days and +3 to +5 days for Kanchan, HD2967 and CG1013, respectively and the Root Mean Square Error (RMSE) observed 2.3, 3.5 and 4.0 days for Kanchan, 1.2, 1.7 and 2.9 days for HD2967 and 1.7, 2.3 and 2.9 days for CG1013, under different date of sowing (D1 to D3). Similarly, the error % ranges was noticed 5.2 to 9.3%, 2.6 to 6.6% and 4.0 to 6.8% for Kanchan, HD2967 and CG1013 varieties from D1 to D3. A very close collaboration between observed and simulated was noticed with R² value of 0.73.

Days taken to Physiological Maturity

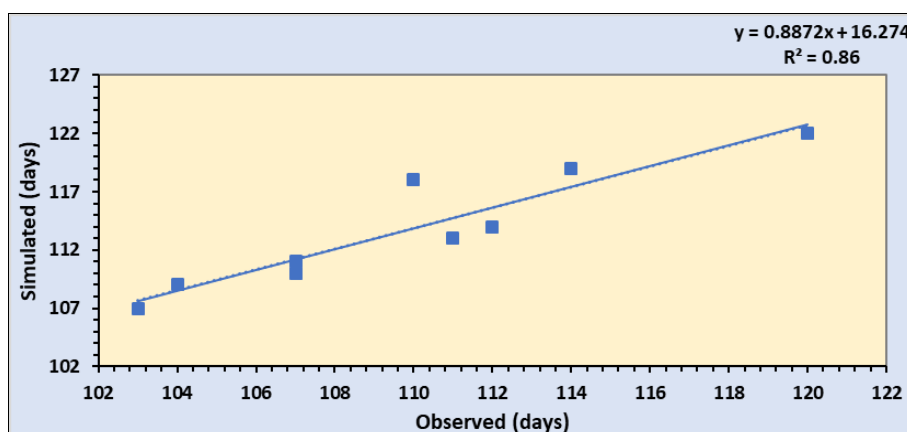
The deviation in physiological maturity was ranges from +2 to +5 days for Kanchan, +2 to +8 days for HD2967 and +2 to +4 days for CG1013 varieties, respectively and RMSE was ranges between 1.2 to 2.9 days for Kanchan, 1.2 to 4.6 days for HD2967 and 1.2 to 2.3 days for CG1013 under different date of sowing (D1 to D3). The error % was found 1.8, 3.6 and 4.6% for Kanchan, 1.6, 4.2 and 6.8% for HD2967 and 1.8, 2.7 and 3.7% for CG1013 varieties, under different growing environments D1 to D3 (Fig. 1(b)).

Yield attributes viz, Grain yield

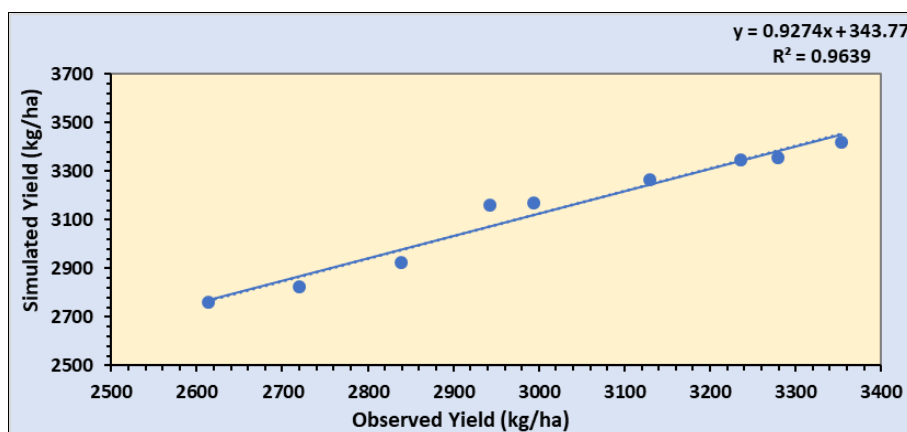
Fig. 1(c) depicted that the deviation varied from 75 to 217 kg/ha for Kanchan, 86 to 147 kg/ha for HD2967 and 67 to 178 kg/ha for CG1013, respectively. The RMSE was ranges between 43.3 to 125.3 kg/ha for Kanchan variety, 49.7 to 84.9 kg/ha for HD2967 variety and 38.7 to 102.8 kg/ha for CG1013 variety. Similarly, error % was varied between 2.2 to 6.9% for Kanchan, 2.9 to 5.3% for HD2967 and 2.0 to 5.6% for CG1013, respectively.



(a)



(b)



(c)

Fig 1: Calibration of DSSAT model for wheat varieties at (a) Anthesis days, (b) Physiological Maturity and (c) Grain yield (kg/ha) under different growing environments

b. Calibration of APSIM model for different varieties of wheat crop

Days taken to Anthesis

The deviation between simulated and observed duration of the anthesis period were recorded +4 to +5 days, +1 to +4 days and +2 to +4 days for Kanchan, HD2967 and CG1013 varieties, respectively and the Root Mean Square Error (RMSE) was found 2.3, 2.3 and 2.9 days for Kanchan, 0.6, 1.2 and 2.3 days for HD2967 and 1.2, 1.7 and 2.3 days for CG1013, respectively under different date of sowing (D1 to D3). Similarly, the error % ranges between 5.2 to 6.8%, 1.3 to 5.3% and 2.7 to 5.6% for Kanchan, HD2967 and CG1013 varieties, respectively under different growing environments D1 to D3. A very close

collaboration between observed and simulated was noticed with R^2 value of 0.82 (Fig. 2(a)).

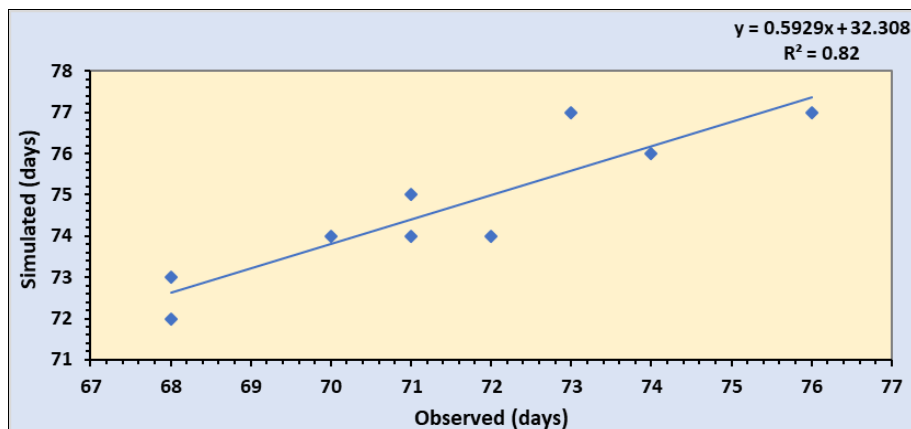
Days taken to Physiological Maturity

The deviation of physiological maturity recorded +1 to +3 days for Kanchan, +2 to +7 days for HD2967 and +1 to +4 days for CG1013 varieties and RMSE was ranges between 0.6 to 1.7 days for Kanchan, 1.2 to 4.0 for HD2967 and 0.6 to 2.3 for CG1013 under different date of sowing (D1 to D3). The error % was found 0.9, 1.8 and 2.8% for Kanchan, 1.6, 3.4 and 6.0% for HD2967 and 0.9, 1.8 and 3.7% for CG1013 varieties, respectively under different dates of sowing D1 to D3 (Fig. 2(b)).

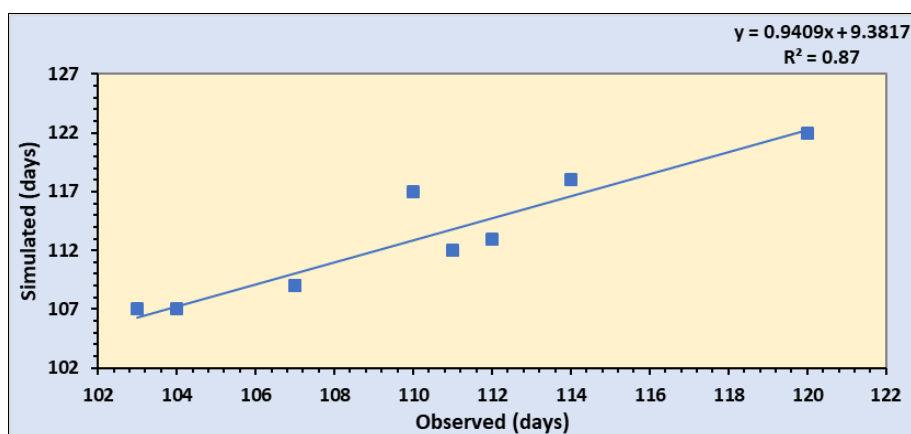
Yield attributes viz, Grain yield

Fig. 2(c) depicted that the deviation varied from 100.0 to 242.2 kg/ha for Kanchan, 117.6 to 189.3 kg/ha for HD2967 and 84.8 to 207.9 kg/ha for CG1013, respectively. The RMSE was ranges between 57.7 to 139.8 kg/ha for Kanchan variety, 67.9 to 109.3

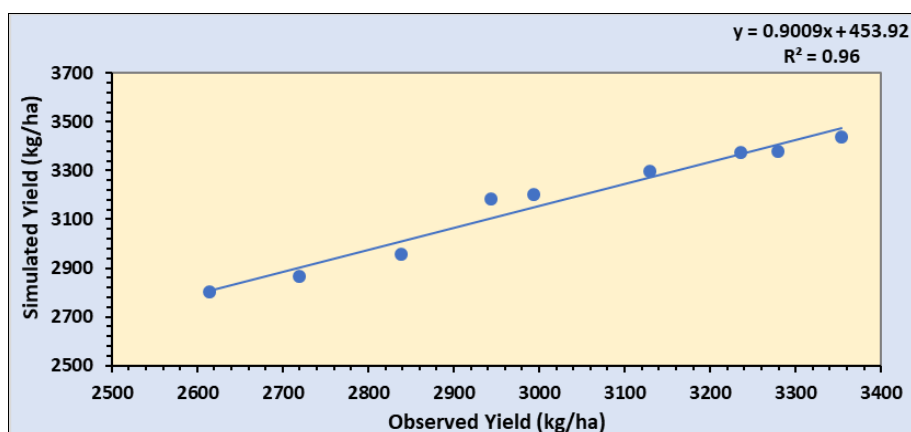
kg/ha for HD2967 variety and 49.0 to 120.0 kg/ha for CG1013 variety. Similarly, error % was found between 3.0 to 7.6% for Kanchan, 4.0 to 6.8% for HD2967 and 2.5 to 6.5% for CG1013 varieties, respectively under different dates of sowing.



(a)



(b)



(c)

Fig 2: Calibration of APSIM model for wheat varieties at (a) Anthesis days, (b) Physiological Maturity and (c) Grain yield (kg/ha) under different growing environments

2. Validation of DSSAT and APSIM models for different varieties of wheat crop

For validation of the DSSAT and APSIM models, field experimental data of the year 2022-23 were used. The genetic coefficients required in models for three different varieties of wheat which obtained by using available input parameters for each variety and running the model iteratively till the prediction

of anthesis, physiological maturity and grain yield showed variation less than 10% from observed values.

A. Validation of the DSSAT model for different varieties of wheat crop

Days taken to Anthesis

Fig 3(a) revealed that the deviation between simulated and

observed duration of anthesis were recorded +2 to +6 days, +2 to +4 days and +1 to +4 days for Kanchan, HD2967 and CG1013, respectively and the Root Mean Square Error (RMSE) observed 1.2, 2.9 and 3.5 days for Kanchan variety, 1.2, 1.7 and 2.3 days for HD2967 variety and 0.6, 1.2 and 2.3 days for CG1013 variety, under different dates of sowing (D1 to D3). Similarly, the error % ranges between 2.8 to 8.7%, 2.7 to 5.7% and 1.4 to 5.9% for Kanchan, HD2967 and CG1013 varieties, respectively from D1 to D3. A very close collaboration between observed and simulated was noticed with R^2 value of 0.64.

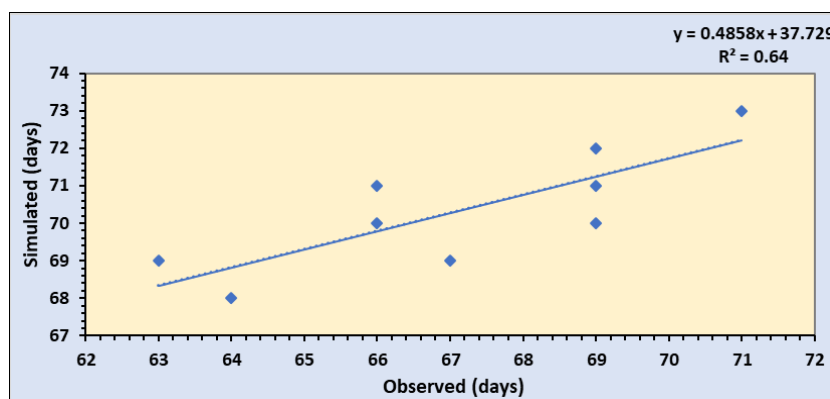
Days taken to Physiological Maturity

The deviation in physiological maturity varied from +2 to +7 days for Kanchan variety, +4 to +9 days for HD2967 variety and +2 to +5 days for CG1013 variety, respectively under different growing environments. The RMSE was ranges between 1.2 to 4.0 days for Kanchan variety, 2.3 to 5.2 days for HD2967

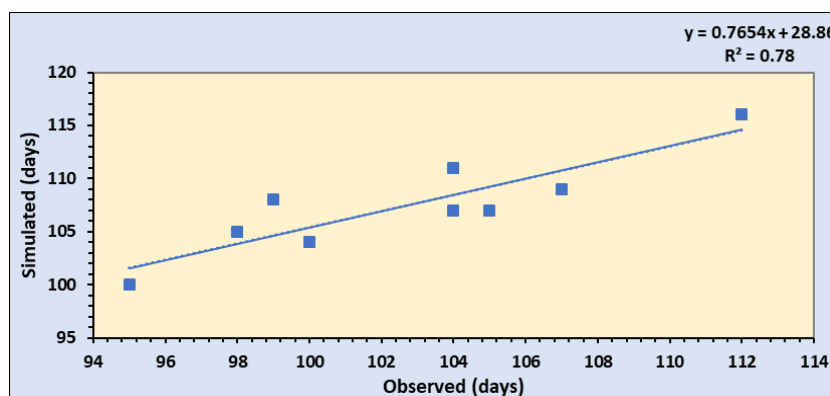
variety and 1.2 to 2.9 days for CG1013 variety from D1 to D3. The error % for physiological maturity was found 1.8, 2.8 and 6.7% for Kanchan variety, 3.4, 6.3 and 8.3% for HD2967 variety and 1.9, 3.8 and 5.0% for CG1013 variety, respectively from D1 to D3 (Fig. 3(b)).

Yield attributes viz, Grain yield

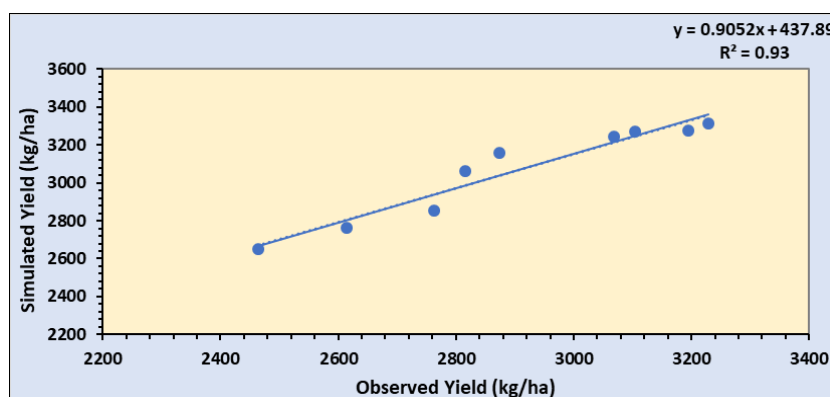
The deviation varied from 83 to 282 kg/ha for Kanchan variety, 93 to 188 kg/ha for HD2967 variety and 87 to 247 kg/ha for CG1013 variety, respectively from D1 to D3. The RMSE was ranges between 47.9 to 162.8 kg/ha for Kanchan variety, 53.7 to 108.5 kg/ha for HD2967 variety and 50.2 to 142.6 kg/ha for CG1013 variety under different growing environments. Similarly, the error % was varied between 2.5 to 8.9% for Kanchan variety, 3.3 to 7.1% for HD2967 variety and 2.6 to 8.1% for CG1013 variety from D1 to D3 (Fig. 3(c)).



(a)



(b)



(c)

Fig 3: Validation of DSSAT model for wheat varieties at (a) Anthesis days, (b) Physiological Maturity and (c) Grain yield (kg/ha) under different growing environments

B. Validation of APSIM model for different varieties of wheat crop

Days taken to Anthesis

Fig. 4(a) revealed that the deviation between simulated and observed duration of anthesis were recorded +1 to +4 days, +1 to +3 days and +1 to -1 days for Kanchan, HD2967 and CG1013, respectively and the Root Mean Square Error (RMSE) observed 0.6, 1.7 and 2.3 days for Kanchan variety, 0.6, 1.2 and 1.7 days for HD2967 variety and 0.6, 1.2 and 0.6 days for CG1013 variety, respectively under different dates of sowing (D1 to D3). Similarly, the error % ranges were noticed 1.4 to 6.0%, 1.4 to 4.3% and 1.4 to -1.6% for Kanchan, HD2967 and CG1013 varieties from D1 to D3. A very close collaboration between observed and simulated was noticed with R^2 value of 0.70.

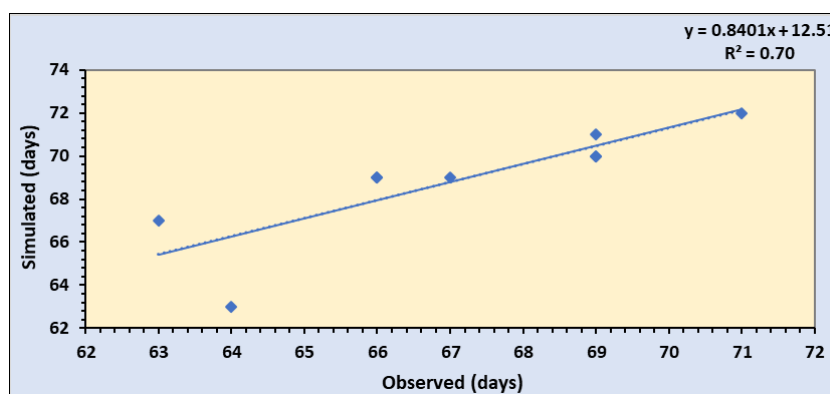
Days taken to Physiological Maturity

The deviation in physiological maturity was ranges from -2 to -4 days for Kanchan, -1 to +6 days for HD2967 and -1 to -3 days

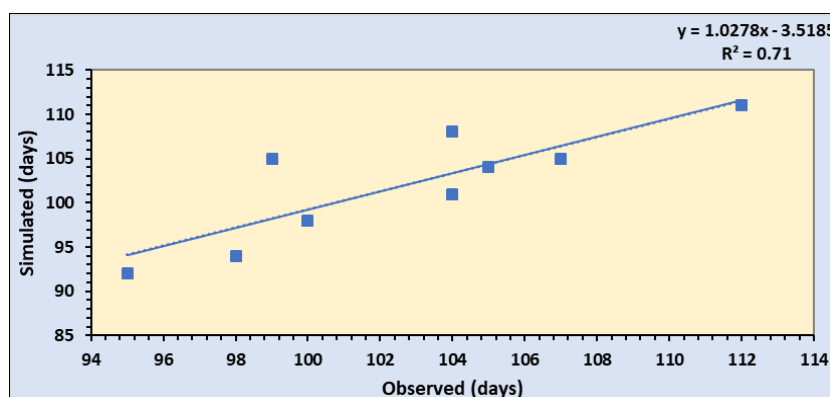
for CG1013 varieties, respectively and RMSE was ranges between 1.2 to 2.3 days for Kanchan, 0.6 to 3.5 days for HD2967 and 0.6 to 1.7 days for CG1013 under different dates of sowing (D1 to D3). The error % was found -1.9, -3.0 and -4.3% for Kanchan, -0.9, 3.7 and 5.7% for HD2967 and -1.0, -2.0 and -3.3% for CG1013 varieties, under different growing environments D1 to D3 (Fig. 4(b)).

Yield attributes viz, Grain yield

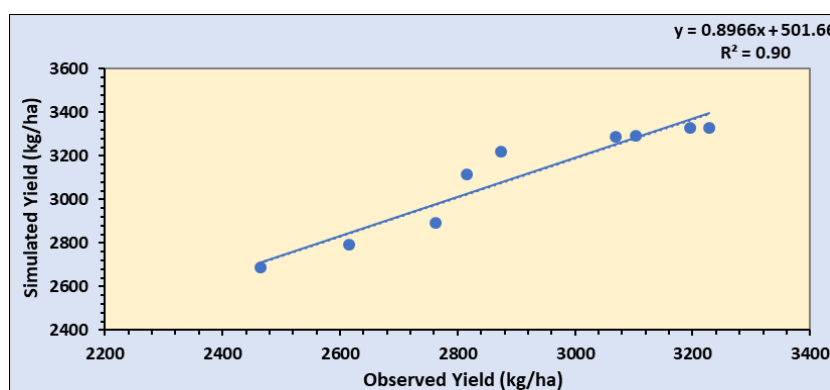
Fig. 4(c) depicted that the deviation varied from 133.7 to 343.9 kg/ha for Kanchan variety, 130.8 to 222.3 kg/ha for HD2967 variety and 97.7 to 300.6 kg/ha for CG1013 variety, respectively under different growing environments. The RMSE was ranges between 77.2 to 198.6 kg/ha for Kanchan variety, 75.5 to 128.3 kg/ha for HD2967 variety and 56.4 to 173.6 kg/ha for CG1013 variety. Similarly, error % was varied between 4.0 to 10.7% for Kanchan variety, 4.5 to 8.3% for HD2967 variety and 2.9 to 9.6% for CG1013 variety, respectively.



(a)



(b)



(c)

Fig 4: Validation of APSIM model for wheat varieties at (a) Anthesis days, (b) Physiological Maturity and (c) Grain yield (kg/ha) under different growing environments

The calibration and validation of the DSSAT CERES-wheat model and APSIM model will be useful for further applications and decision-making in the Raipur district. It can be used to estimate crop production and water management to evaluate the effect of climate changes or soil fertility changes.

The performance of the model was acceptable because the deviation % between the simulated and observed values was less than 10% and R^2 values was more than 60. Therefore, the model can predict phenological stages and yield of all cultivars with good accuracy. The nRMSE values at all the locations for days taken for anthesis and maturity, were in the excellent range ($<10\%$) as proposed by Jamieson *et al.*, (1991)^[9].

Chisanga *et al.*, (2021)^[7] The APSIM-Maize and DSSAT-CERES-Maize models were calibrated and validated for phenology, maximum leaf area index (mLAI), soil water content, aboveground biomass, and grain yield under both rainfed and irrigated conditions. The findings indicated that both models effectively simulated grain yield, grain number per square meter, and soil water content across soil layers 1–8, with normalized RMSE (RMSEn) not exceeding 20%. Additionally, biomass and grain yield were simulated with an RMSEn of $\leq 30\%$ under rainfed conditions. Model validation under irrigated

conditions demonstrated satisfactory performance.

Ahmed *et al.*, (2016)^[2] The APSIM and DSSAT-CERES-Wheat models were calibrated, demonstrating realistic performance through accurate simulations of crop phenology, leaf area index (LAI), biomass, and grain yield compared to observed data. Both models effectively predicted anthesis and maturity dates, maximum LAI, biomass, and grain yield, with a normalized root mean square error (nRMSE) below 10%, a D-index exceeding 0.80, and model efficiency above 80% in most cases.

Akinseye *et al.*, (2017)^[3] The APSIM, DSSAT, and SAMARA models were calibrated and validated for sorghum using detailed growth and development data from field trials conducted in the semi-arid region of West Africa. The results indicated that these models effectively simulated phenology and leaf development in photoperiod-sensitive (PPS) sorghum varieties from West Africa. However, they struggled to accurately predict assimilate partitioning during the grain-filling stage. Among the models, APSIM and SAMARA, being more mechanistic, exhibited greater sensitivity to key parameter adjustments—specifically, APSIM showed higher sensitivity to specific leaf area in low-PPS varieties, while SAMARA responded more strongly to parameter changes in high-PPS varieties.

Table 3: Calibration of DSSAT and APSIM models for three wheat varieties (Kanchan, HD2967 and CG1013) at anthesis, physiological maturity and grain yield under different growing environments

OBSERVE		DSSAT	PE	RMSE	NRMSE	APSIM	PE	RMSE	NRMSE
Anthesis Days									
Kanchan									
D1	73.0	77.0	5.2	2.3	3.3	77.0	5.2	2.3	3.3
D2	70.0	76.0	7.9	3.5	4.9	74.0	5.4	2.3	3.3
D3	68.0	75.0	9.3	4.0	5.7	73.0	6.8	2.9	4.1
HD2967									
D1	76.0	78.0	2.6	1.2	1.6	77.0	1.3	0.6	0.8
D2	74.0	77.0	3.9	1.7	2.4	76.0	2.6	1.2	1.6
D3	71.0	76.0	6.6	2.9	3.9	75.0	5.3	2.3	3.1
CG1013									
D1	72.0	75.0	4.0	1.7	2.5	74.0	2.7	1.2	1.6
D2	71.0	75.0	5.3	2.3	3.3	74.0	4.1	1.7	2.5
D3	68.0	73.0	6.8	2.9	4.1	72.0	5.6	2.3	3.3
Maturity Days									
Kanchan									
D1	112.0	114.0	1.8	1.2	1.1	113.0	0.9	0.6	0.5
D2	107.0	111.0	3.6	2.3	2.1	109.0	1.8	1.2	1.1
D3	104.0	109.0	4.6	2.9	2.7	107.0	2.8	1.7	1.6
HD2967									
D1	120.0	122.0	1.6	1.2	1.0	122.0	1.6	1.2	1.0
D2	114.0	119.0	4.2	2.9	2.5	118.0	3.4	2.3	2.0
D3	110.0	118.0	6.8	4.6	4.0	117.0	6.0	4.0	3.5
CG1013									
D1	111.0	113.0	1.8	1.2	1.1	112.0	0.9	0.6	0.5
D2	107.0	110.0	2.7	1.7	1.6	109.0	1.8	1.2	1.1
D3	103.0	107.0	3.7	2.3	2.2	107.0	3.7	2.3	2.2
Grain Yields									
Kanchan									
D1	3279.0	3354.0	2.2	43.3	1.4	3379.0	3.0	57.7	1.9
D2	3129.0	3267.0	4.2	79.7	2.6	3299.0	5.2	98.1	3.1
D3	2943.0	3160.0	6.9	125.3	4.0	3185.2	7.6	139.8	4.5
HD2967									
D1	2839.0	2925.0	2.9	49.7	1.8	2956.6	4.0	67.9	2.5
D2	2720.0	2826.0	3.8	61.2	2.2	2868.2	5.2	85.6	3.1
D3	2614.0	2761.0	5.3	84.9	3.1	2803.3	6.8	109.3	4.0
CG1013									
D1	3353.0	3420.0	2.0	38.7	1.2	3437.8	2.5	49.0	1.5
D2	3236.0	3347.0	3.3	64.1	2.0	3375.4	4.1	80.5	2.5
D3	2994.0	3172.0	5.6	102.8	3.2	3201.9	6.5	120.0	3.8

Table 4: Validation of DSSAT and APSIM models for three wheat varieties (Kanchan, HD2967 and CG1013) at anthesis, physiological maturity and grain yield under different growing environments

OBSERVE		DSSAT	PE	RMSE	NRMSE	APSIM	PE	RMSE	NRMSE
Anthesis Days									
Kanchan									
D1	69.0	71.0	2.8	1.2	1.7	70.0	1.4	0.6	0.9
D2	66.0	71.0	7.0	2.9	4.4	69.0	4.3	1.7	2.6
D3	63.0	69.0	8.7	3.5	5.2	67.0	6.0	2.3	3.5
HD2967									
D1	71.0	73.0	2.7	1.2	1.7	72.0	1.4	0.6	0.8
D2	69.0	72.0	4.2	1.7	2.5	71.0	2.8	1.2	1.7
D3	66.0	70.0	5.7	2.3	3.4	69.0	4.3	1.7	2.5
CG1013									
D1	69.0	70.0	1.4	0.6	0.9	70.0	1.4	0.6	0.9
D2	67.0	69.0	2.9	1.2	1.7	69.0	2.9	1.2	1.7
D3	64.0	68.0	5.9	2.3	3.5	63.0	-1.6	0.6	0.9
Maturity Days									
Kanchan									
D1	107.0	109.0	1.8	1.2	1.1	105.0	-1.9	1.2	1.1
D2	104.0	107.0	2.8	1.7	1.7	101.0	-3.0	1.7	1.7
D3	98.0	105.0	6.7	4.0	3.9	94.0	-4.3	2.3	2.2
HD2967									
D1	112.0	116.0	3.4	2.3	2.2	111.0	-0.9	0.6	0.5
D2	104.0	111.0	6.3	4.0	3.8	108.0	3.7	2.3	2.2
D3	99.0	108.0	8.3	5.2	4.9	105.0	5.7	3.5	3.3
CG1013									
D1	105.0	107.0	1.9	1.2	1.2	104.0	-1.0	0.6	0.6
D2	100.0	104.0	3.8	2.3	2.3	98.0	-2.0	1.2	1.2
D3	95.0	100.0	5.0	2.9	2.9	92.0	-3.3	1.7	1.7
Grain Yields									
Kanchan									
D1	3195.0	3278.0	2.5	47.9	1.6	3328.7	4.0	77.2	2.5
D2	3069.0	3242.0	5.3	99.9	3.3	3287.3	6.6	126.0	4.1
D3	2874.0	3156.0	8.9	162.8	5.3	3217.9	10.7	198.6	6.5
HD2967									
D1	2762.0	2855.0	3.3	53.7	2.1	2892.8	4.5	75.5	2.9
D2	2615.0	2762.0	5.3	84.9	3.2	2792.0	6.3	102.2	3.9
D3	2464.0	2652.0	7.1	108.5	4.2	2686.3	8.3	128.3	4.9
CG1013									
D1	3229.0	3316.0	2.6	50.2	1.6	3326.7	2.9	56.4	1.8
D2	3104.0	3269.0	5.0	95.3	3.1	3293.2	5.7	109.2	3.6
D3	2815.0	3062.0	8.1	142.6	4.7	3115.6	9.6	173.6	5.7

Conclusion

The calibration and validation of DSSAT and APSIM models for wheat cultivars Kanchan, HD2967 and CG1013 provided valuable insights into the accuracy and reliability of these models for predicting wheat growth and yield under varying sowing dates. The models demonstrated good performance in simulating key phenological stages, such as anthesis and physiological maturity, as well as grain yield, with statistical indicators like RMSE and R^2 confirming their robustness.

The results indicate that both models can be effectively used to simulate wheat growth and yield. APSIM model shows slightly better accuracy in phenological of growth stages but DSSAT model predict grain yield with good accuracy. These models are useful tools for optimizing sowing dates and management practices in wheat cultivation, helping to improve decision-making in response to climatic variations and soil fertility changes.

References

- Aggarwal PK, Sinha SK. Effect of probable increase in carbon dioxide and temperature on wheat yields in India. *J Agric Meteorol.* 1993;48(5):811-814.
- Ahmed M, Akram MN, Asim M, Aslam M, Hassan FU, Higgins S, Stöckle CO, Hoogenboom G. Calibration and validation of APSIM-Wheat and CERES-Wheat for spring wheat under rainfed conditions: Models evaluation and application. *Comput Electron Agric.* 2016;123:384-401.
- Akinseye FM, Adam M, Agele SO, Hoffmann MP, Traore PCS, Whitbread AM. Assessing crop model improvements through comparison of sorghum (*Sorghum bicolor* L. Moench) simulation models: A case study of West African varieties. *Field Crops Res.* 2017;201:19-31.
- Al-Khatib K, Paulsen GM. Mode of high-temperature injury to wheat during grain development. *Physiologia Plantarum.* 1984;61(3):363-368.
- Anonymous. Directorate of Agriculture, Govt. of Chhattisgarh, Raipur, 2022-23. 2024. p. 4-5.
- Bannayan M, Hoogenboom G. Using pattern recognition for assessing simulation models: A new methodology for optimizing DSSAT models. *Agric Syst.* 2009;99(1):30-40.
- Chisanga CB, Phiri E, Chinene VR. Evaluating APSIM-and-DSSAT-CERES-Maize models under rainfed conditions using Zambian rainfed maize cultivars. *Nitrogen.* 2021;2(4):392-414.
- FAO. Production: Crops and livestock products. In: FAOSTAT. Rome. [cited October 2023]. Available from:

<https://www.fao.org/faostat/en/#data/QCL>

9. Jamieson PD, Porter JR, Wilson DR. A test of the computer simulation model ARCWHEAT1 on wheat crops grown in New Zealand. *Field Crops Res.* 1991;27(4):337-350.
10. Lal M, Singh KK, Rathore LS, Srinivasan G, Saseendran SA. Vulnerability of rice and wheat yields in NW India to future changes in climate. *Agric For Meteorol.* 1998;89(2):101-114.
11. Leffelaar PA. Basic elements of dynamic simulation. In: *Systems analysis and simulation of ecological processes with examples in CSMP and FORTRAN.* 1993. p. 11-27.
12. Rosenzweig C, Iglesias A. The use of crop models for international climate change impact assessment. In: Tsuji GY, Hoogenboom G, Thornton PK, editors. *Understanding options for agricultural production.* Dordrecht: Kluwer Academic Publisher; 1998. p. 267-292.
13. Saini AD, Nanda R. Analysis of temperature and photoperiodic response to flowering in wheat. *Indian J Agric Sci.* 1987;57:351-359.
14. Sastri ASRAS. Climate change in Indian sub-continent and its impact on agriculture. *Nova Acta Leopoldina.* 2010;384:227-240.
15. Talukder AS, McDonald MH, Gill GS. Effect of short-term heat stress prior to flowering and at early grain set on the utilization of water-soluble carbohydrates by wheat genotypes. *Field Crops Res.* 2013;147:1-11.
16. Zhao H, Dai T, Jiang D, Cao W. Effects of high temperature on key enzymes involved in starch and protein formation in grains of two wheat cultivars. *J Agron Crop Sci.* 2008;194(1):47-54.