Original Research Article

Calibration and validation of CERES-Wheat model for wheat varieties under Raipur District of Chhattisgarh

ABSTRACT

The current study "Calibration and validation of CERES-Wheat model for wheat varieties under Raipur district of Chhattisgarh" was carried out in the Department of Agrometerology, IGKV, Raipur, for which a field experiment was done at the college of Agriculture's farm field Raipur at latitude of 21.25' N, longitudes 81.62'E and altitude 289.5 m above mean sea level. Along with 3 wheat variety (Kanchan, HD2967 and CG1013) and three growing environment D1 (26th Nov), D2 (06th Dec) and D3 (16th Dec). This paper aimed to Genetic co-efficient of three wheat varieties determined and calibration & validation the DSSAT model. Result of study revealed that closer estimation of Validation shows days to anthesis, days to maturity and grain yields % of error and Root mean square erro (RMSE) observed values were 2.8%, 2.8%, 4.2% of error and 1.41%,1.41%, 2.12% RMSE in D1, D2, D3 for Kanchan variety and HD2967 were observed 1.4%, 4.1%, 5.6% of error and 0.71%, 2.12%, 2.83% of RMSE respectively. CG1013 observed in 1.4%, 4.2%, 7.0% of error and 0.71%, 2.12%, 3.54% RMSE respectively. Days to maturity observed in 2.7%, 6.5%, 8.6% of error and 2.12%, 4.93%, 6.36% RMSE in D1, D2, D3 for Kanchan variety and HD2967 were observed 2.7%, 1.8%, 7.4% of error and 2.12%, 1.41%, 5.66% RMSE respectively. CG1013 observed values were 0.9%, 4.7%, 7.7% and RMSE observed were 0.71%, 3.54%, 5.66% respectively. Grain yield observed were 3.9%, 1.1%, 0.6% of error and 81.32%, 21.92%, 11.31% RMSE in D1, D2, D3 for Kanchan variety and HD2967 were observed 2.7%, -2.1, 0.8% and 47.38%, 31.82%, 12.02% of RMSE respectively. CG1013 observed in 0.8%, 4.1%, 0.5% and 17.68%, 84.85%, 9.90% RMSE respectively. The model has been successfully calibrated and validated for wheat growing in Raipur, Chhattisgarh environment and can now it can be taken for further applications in natural resources management and climate change impact studies. The model performance was evaluated using % of error and RMSE and it was observed that DASST CERES model was able to predict the growth parameters like days to anthsis, day to maturity and grain yield with reasonably good accuracy (error% less than 10).

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Key words: DSSAT-CERES model, wheat, Genetic co-efficient, Chhattisgarh, RMSE%, calibration and validation.

1. Introduction –

Wheat (*Triticum aestivum* L) is the most widely cultivated food grain crop of the world. It is grown not only in temperate zones but also in tropical and subtropical zones. In India, wheat is the second important staple food crop, rice after the (Agrawal and Sinha, 1993). India is second largest producer of wheat in the world after China with about 12% share in total world wheat production. In India, wheat are cultivated on an area of 9.75 million ha, with a production of 6.46 million tones and productivity of 662.56 kg/ha in 1950- 1951 has gradually increased up to 29.58 million ha, with a production of 99.70million tones and productivity of 3371 kg/ha during 2011-2012.The production of wheat has also showed an increasing trend, from 87.39 to 94.57 million tonnes from 2012–13 to 2017–18 with a magnitude of 7.18 million tonnes (8.22%).Uttar Pradesh still holds the 1st position of largest producer in the country accounting for about 110 million tonnes the total production, during 2021-22. In Chhattisgarh the total wheat crops growing area is 99924 (thousand ha) and where production 166978 (thousand tonne) and productivity 1671.05 kg/ha during the year 2018-2019.

Crop models are effective tools to predict crop productivity under different management options and climatic conditions. In the contest of climate change, importance of crop model in simulating crop production under different climatic scenario was increasing day by day. DSSAT is a popular crop model used over 100 countries for more than 20 years. DSSAT includes more than 40 crop growth model. Among them, CERES-Wheat is most widely used crop simulation model.

Calibration refer to adjustment made to model parameters so as to give the most accurate comparison between simulated result and result obtained from field measurements, in other words calibration involves the adjustment of certain model parameters by systematically comparing simulated result to field observation of state variables. Validation is the process by which a simulation model is compare to feel data not used previously in the development of calibration process simulated state variables are compared with measured values of state variables for example measure of leaf area is compared with simulated values. Looking these

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aspects the present study has been undertaken to assess the DSSAT model for different verities of wheat grown in Raipur Chhattisgarh.

2. Materials and Methods

2.1 Site description

The study was conducted in *rabi* seasen 2019-20 and 2020-21 at Agromet Research Field of IGKV Raipur. Which situated in near center part of Chhattisgarh at latitude 21.16 °N, longitude 81.36 °E and altitude of 289.5 m and above mean sea level.

2.2 DSSAT (CERES-Wheat) Model

DSSAT (CERES-Wheat) Model DSSAT v4.6 was used for simulating wheat yields in growing environments of Raipur. The model runs with five sets of data: i. Soil file, ii. Weather file, iii. Genetic coefficients, iv. Experimental (X) file, v. Time course (T) file and vi. Annual(A) file. Soil data included soil characteristics such as site latitude and longitude, soil type and soil series, pH, bulk density, soil texture and soil N and C content Weather file included temperature (both maximum and minimum), humidity, sunshine hours, rainfall. DSSAT model required some of crop management data [crop, cultivar, planting date, row and plant spacing, fertilizer levels, tillage practices and organic amendments in experimental file to simulate crop productivity. Data on physiological stages of crop growth such as anthesis dates, days to maturity and grain yield were also included in A and T files. The crop management data were recorded throughout the growing seasons. The input files, such as weather file, soil file, and A & T files, were created for running of the model. The model were calibrated with set of field experimental data and subsequently validated with another dataset of field experiments. Seven characters of wheat were needed in CERES Wheat model in DSSAT

Table-1: Description of different genetic characters of wheat for use in model

Name of parameters	Definition
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.

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G1	Kernel number per unit canopy weight at anthesis.
G2	Standard kernel size under optimum conditions (mg).
G3	Standard, non-stressed mature tiller wt. (including grain) (g dwt)
PHINT	Interval between successive leaf tip appearances.

2.3 Cultivar specific genetic coefficients

Genetic co-efficient of wheat was determined for seven characters viz. P1V, PID, P5, G1, G2, G3 and PHINT. Description of the genetic co-efficient was described in Table 2. Genetic co-efficient of G1, G2 and G3 of wheat varieties were determined manually from field experiments on average basis.

The genetic coefficients P1V for all varieties were 16, because wheat varieties grown in Raipur are spring wheat. P1D, Value of genetic co-efficient for Kanchan, HD2967 and CG1013 were 19, 27 and 21 days, respectively. HD2967 has the highest (950) value P5. followed by Kanchan (780). The lowest P5, value (760) was obtained for CG1013. G1 for Kanchan, HD2967 and CG1013 were found 22, 19 and 21days, respectively. Similarly, G2 for Kanchan, HD2967 and CG1013 were observed i.e. 21, 19, and 21 respectively. There was considerable variation among the cultivar in G3 but the PHINT were the same amongst the cultivars. All varieties was showed same value (1.3g) for G3and 60 for PHINT.

Table-2: Genetic coefficient of different wheat varieties

Variety	P1V	P1D(% reduction in rate 10 h^{-1} drop in pp)	P5(^{o}C.d)	G1(#/g)	G2(mg)	G3(g dwt)	PHIN(^{o}C.d)
Kanchan	16	19	780	22	21	1.3	60
HD2967	16	27	950	19	19	1.3	60
CG1013	16	21	760	21	21	1.3	60

2.4 Statistical evaluation

Statistical analysis 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 = $[\sum_{i=1}^{n}(Pi - Oi)2/n]1/2$

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Beside the above test criteria, error percent was also calculated in different treatment under study to express the deviation more scientifically.

This is as follow:

Error% = {(simulated – observed) / observed}*

2.5 Model calibration

DSSAT crop models require genetic coefficients, which are cultivar specific for describing processes related to growth and development and grain production. These coefficients allow the model to simulate performance of diverse genotypes under different soil, weather and management conditions. The model was calibrated using field measured values of weather parameters, crop management and soil properties during the 2019–2020 cropping season (Raipur location) of the experiment. Genetic coefficients were estimated by using observed anthesis and physiological maturity data and grain yield of growing season of 2019-2020.

2.6 Validation of model

Validation of model was evaluated by comparing the simulated versus observed values from season date 2020-2021 model was validation for days to anthesis, days to physiological maturity and grain yield.

3. Results and Discussion

3.2 Calibration for different varieties of wheat crop at Raipur District

The data of cropping year 2019-2020 and 2020-21 were used for calibration and validation studies. In this crop season the three cultivars (Kanchan, HD2967 and CG1013) of wheat crop were sown on 3 dates of sowing (26 Nov, 06 Dec and 16 Dec).

Observed and simulated values of phenological events (Anthesis and physiological maturity) and yield attributes *i.e.* grain yield were compared with % error and RMSE. The results of calibration and validation of CERES- Wheat model has been discussed below:

3.2.1 Anthesis

Table 3. revealed that simulated days for anthesis was recorded 73 days but observed value was found 72 days with % of error 1.4% and RMSE 0.71%, in D1(26Nov) for Kanchan

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variety. In D2, observed value was 71 days and simulated value was 75 days with % of error was 5.3% and RMSE 2.83% respectively. Actual value was 70 days and simulated value of 74 days change error% 5.4% and 2.83 of RMSE were observed in D3. Highest % of error and RMSE, were recorded 5.4% in D3 and 2.83% while lowest, were observed in D1, 1.4% and 0.71%.

In HD2967, simulation value was 76 days against the observed value of 75 with 1.3% of error and 0.71% RMSE in first date of sowing. D2 showed simulated value 77 and actual value 73 days was % of error was 5.2% and RMSE 2.83 respectively. Simulated value for antesis in D3 was recorded 76 days against the actual value of 71 days with 6.6% of error and RMSE 3.54%. D3 showed highest % of error and RMSE of 6.6% and 3.54% followed by D2 (5.2 and 2.83%) and D1 (1.3and 0.71 %), respectively.

Table 3, shows that the simulation value of CG1013 for anthesis was found 73, 76, 74 observed values were recorded with 71, 71, 69 along % of error 2.7%, 6.6%, 6.8% and RMSE 1.41, 3.54, 3.54 respective under D1, D2, and D3 respectively. Highest % of error 6.8 and RMSE values 3.54% was found in D3 (16 Dec) and lowest was observed in D1 (26 Nov) 2.7 and 1.41%, respectively.

3.2 .2 Physiological maturity

Table 3 repoted that Kanchan showed the highest % of error was found 2.8% and RMSE 2.12% in D3 (16 Dec) and lowest 1.8% of error and RMSE 1.41% in D1 (26 Nov).Simulated value of physiological maturity observed 114 days, 112 days and 109 days was recorded during D1,D2 and D3, respectively, While observed value were observed 112 days in D1, 110 days in D2 and 106 days in D3 with 1.8%, 1.8%, 2.8% and RMSE % 1.41,1.41, 2.12% in D1,D2 and D3, respectively.

In HD2967, simulation value was 123 days against the observed value 122 with -0.8% of error and 0.71% RMSE in first date of sowing (26 Nov). In D2 (06 Dec) showed simulated value of 120 days, against actual value of 119 days with 0.8% of error and RMSE 0.71%. Third date of sowing (D3) was recorded simulated value of 117 days against the actual value of 115 days with 7.4% of error and RMSE 1.41%. Highest % of error 1.7% and RMSE 1.41% was observed in D3 followed by D1 -0.8% of error and RMSE 0.71% and D2 was observed 0.8% of error and RMSE 0.71% respectively.

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It was observed from the Table 3 that CG1013 variety has taken 112 days for physiological maturity but simulated value showed 113 days with 0.9% of error and RMSE 0.71% in D1 (26 Nov). In D2, simulated value was 112 days and actual value 109 days with % of error were 2.7% and RMSE 2.12% Whereas, D3 showed 106 days for observed value and 109 days for simulated values with 2.8% of error and RMSE 2.12%. Highest % of error 2.8 and RMSE 2.12% was observed in D3 followed by D2 (06 Dec) 2.7% and D1 (26 Nov) 0.9%, 2.12 and 0.71% respectively.

3.2.3 Grain yield

Table 3 revealed that simulated values of grain yield for Kanchan variety were 3167 kg/ha, 3061 kg/ha, 2925 kg/ha against the observed yield of 3135 kg/ha, 2925 kg/ha, 2850 kg/ha with 1.0, 4.4 and 2.6% of error and RMSE 22.63, 96.17 and 53.03% under D1 (26 Nov), D2 (06 Dec) and D3 (16 Dec), respectively. Highest percent of error 4.4 and 96.17% RMSE was recorded in D2 (06 Nov) and lowest % of error 1.0% and RMSE 22.63% was observed in D1(26 Nov).

HD2967 variety showed simulated grain yield of 2553 kg/ha in D1 (26 Nov) against the observed yield of 2454 kg/ha with 3.9% of error and RMSE 70.00%. In D2, HD 2967 variety showed 2390 kg/ha simulated grain yield against 2360 kg/ha observed yield with 1.3% of error and RMSE 21.21. Simulated grain yield 2341 kg/ha was found in D3 while observed grain yield was 2250 kg/ha along with 3.9% of error and RMSE 64.35%.

Simulated grain yield of CG1013 was found 3107 kg/ha, 3079 kg/ha, 3049 kg/ha against the observed value of 3068 kg/ha, 2970 kg/ha, 2885 kg/ha under D1, D2 and D3 respectively and RMSE 27.58. % of error was 5.4% and RMSE value 115.97%. The results are considered acceptable if the difference between simulated yield and actual yield is lower than 10 % as per (Loague and Green 1991). (Patel *et al.*2010) reported that optimum sowing date (D_2–15^{th} Nov.)

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Table 3. Calibration of 3 wheat varites (Kanchan, HD2967 and CG1013) **for days to anthesis, days to maturity and grain yield under different growing environment,**

	Days to anthesis				Days to maturity				Grain yield (Kg/ha)			
Variety	**Obs value**	**Sim value**	**Error (%)**	**RMSE (%)**	**Obs value**	**Sim value**	**Error (%)**	**RMSE (%)**	**Obs value**	**Sim value**	**Error (%)**	**RMSE (%)**
V1												
Kanchan	72	73	1.4	0.71	112	114	1.8	1.41	3135	3167	1.0	22.63
	71	75	5.3	2.83	110	112	1.8	1.41	2925	3061	4.4	96.17
	70	74	5.4	2.83	106	109	2.8	2.12	2850	2925	2.6	53.03
V2												
HD2967	75	76	1.3	0.71	123	122	-0.8	0.71	2454	2553	3.9	70.00
	73	77	5.2	2.83	119	120	0.8	0.71	2360	2390	1.3	21.21
	71	76	6.6	3.54	115	117	1.7	1.41	2250	2341	3.9	64.35
V3												
CG1013	71	73	2.7	1.41	112	113	0.9	0.71	3068	3107	1.3	27.58
	71	76	6.6	3.54	109	112	2.7	2.12	2970	3079	3.5	77.07
	69	74	6.8	3.54	106	109	2.8	2.12	2885	3049	5.4	115.97

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3.3 Validation of CERES-wheat model for different varieties of wheat crop at Raipur station.

3.3.1 Anthesis

The simulated days for anthesis was 72 days, but observed value was found 70 days, witch % of error 2.8 and RMSE 1.41%, according to Table 4 Kanchan variety in D1 (26 Nov). In D2, the observed value was 69 days, whereas the simulated value was 71 days, with a 2.8% error and 1.41% RMSE. In D3, the actual value was 68 days and the simulated value was 71 days with a 4.2% error and RMSE 2.12% in accuracy. The highest percent of errors and RMSE were found in D3 (4.2% and 2.12%), while the lowest was found in D1 (2.8 and 1.41%) respectively.

In HD2967, simulation value was 73 days against the observed value of 72 with 1.4% error and 0.71% RMSE in first date of sowing. D2 showed simulated value 73 and actual value 70 days witch % of error 4.1% and 2.12% RMSE. Simulated value was recorded 72 days against the actual value of 68 days with 5.6% error and 2.83% RMSE. D3 showed highest % of error and RMSE of 5.6 and 2.83% followed by D2 4.1% error and 2.12% RMSE and D1 1.4% error and 0.71% RMSE respectively.

From table 4, the simulation value of CG1013 for anthesis was found 71, 71, 71 observed values was recorded with 70, 68, 66 along % of error 1.4%, 4.2%, 7.0% and RMSE 0.71, 2.12, 3.54 at D1, D2 and D3, respectively. Highest % of error 7.0% and RMSE 3.54% were found in D3 (16 Dec) and lowest was observed in D1 (26 Nov) 1.4 and 0.71%.

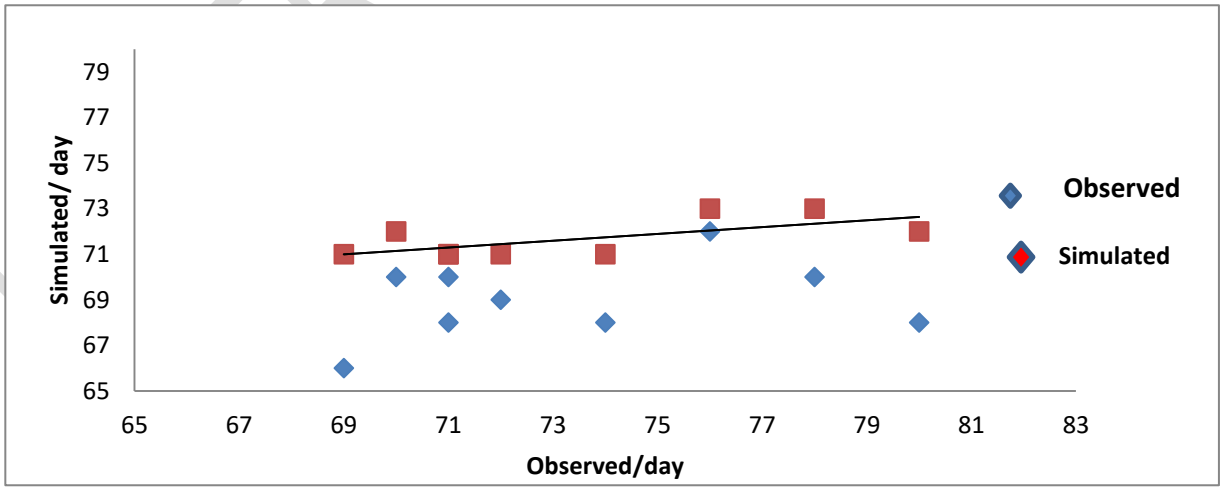

Fig.1 Relationship between simulated and observed anthesis (day) of wheat cultivars.

3.3.2 Physiological maturity

Kanchan seemed to have the highest percent of error (8.6%) and RMSE (6.36%) in D3 (16 Dec) and the lowest percent of error (3.6%) and RMSE (2.83%) in D1 (26 Nov). Simulated physiological maturity values were observed 110 days, 108 days, and 105 days was recorded darning D1, D2, and D3, respectively, whereas observed values were observed 106 days in D1, 101 days in D2, and 96 days in D3, respectively, with 3.6%, 6.5%, 8.6% of error and RMSE observed were 2.83, 4.95, 6.36 in D1, D2, and D3, respectively.

In HD2967, simulation value was 113 days against the observed value 110 with 2.7% errors and 2.12% RMSE in first date of sowing (26 Nov). D2 (06 Dec) showed simulated value of 110 days, against the actual value of 108 days with 1.8% error and 1.41% RMSE. Third date of sowing (D3) was recorded simulated value of 108 days against the actual value of 100 days with 7.4% error and 5.66% RMSE. Highest % of error and RMSE 7.4 and 5.66% was observed in D3 followed by D1 2.7% error and 2.12% RMSE and D2 1.8% error and 1.41%RMSE respectively.

It was observed from the Table 4 that CG1013 variety has taken 107 days for physiological maturity but simulated value showed 108 days with 0.9% error and 0.71% RMSE in D1 (26 Nov). In D2, simulated value was 106 days and actual value 101 days with % of error were 4.7% and 3.54% RMSE Whereas D3 showed 96 days for observed value and 104 days for simulated values with 7.7% error and 5.66% RMSE. Highest % of error and RMSE 7.7% and 5.66% were observed in D3 followed by D2 (06 Dec) 4.7% error and 3.54% RMSE and D1 (26 Nov) 0.9% error and 0.71% RMSE respectively.

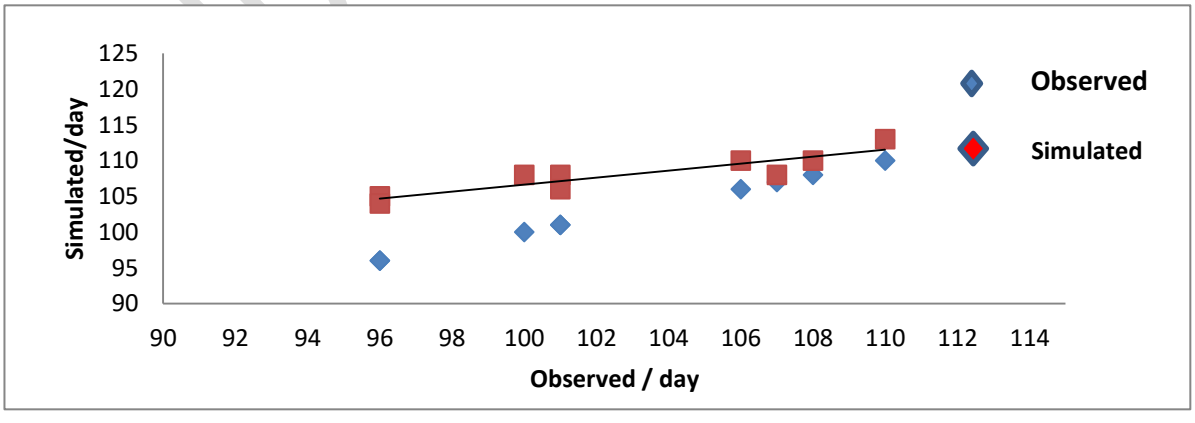

Fig: 2 Relationship between simulated and observed maturity (day) of wheat cultivars.

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3.3.3 Grain yield

Table 4, revealed that simulated values of grain yield for Kanchan variety were 2965 kg/ha, 2816 kg/ha, 2716 kg/ha against the observed yield of 2850 kg/ha, 2785 kg/ha, 2700 kg/ha with 3.9, 1.1, 0.6% error and 81.32, 21.92, 11.31% of RMSE under D1 (26 Nov), D2 (06 Dec) and D3 (16 Dec), respectively. Highest percent of error 3.9% and RMSE 81.32% was recorded in D1 (26 Nov) and lowest values 0.6% error and 11.31% RMSE was observed in D3 (16 Dec).

HD2967 variety showed simulated grain yield of 2447 kg/ha in D1 (26 Nov) against the observed yield of 2380 kg/ha with 2.7% error and 47.38% of RMSE. In D2, HD 2967 variety showed 2185 kg/ha simulated grain yield against 2230 kg/ha observed yield with -2.1% error and 31.82 % of RMSE. Simulated grain yield 2162 kg/ha was found in D3 while observed grain yield was 2145 kg/ha along with 0.8% error and 12.02% of RMSE.

Simulated grain yield of CG1013 was found 2960 kg/ha, 2932 kg/ha, 2744 kg/ha against the observed value of 2935 kg/ha, 2812 kg/ha, 2730 kg/ha under D1, D2 and D3 respectively. D3 showed lowest % of error 0.5% and 9.90% RMSE and D2 showed highest % of error 4.1% and 84.85% RMSE.

The results are considered acceptable if the difference between simulated yield and actual yield is lower than 10 % as per validation was found better as compared to early (D1–1stNov.) and late (D3–30th Nov.) sowings. Similar results were also reported by Sreenivas and Reddy (2013).

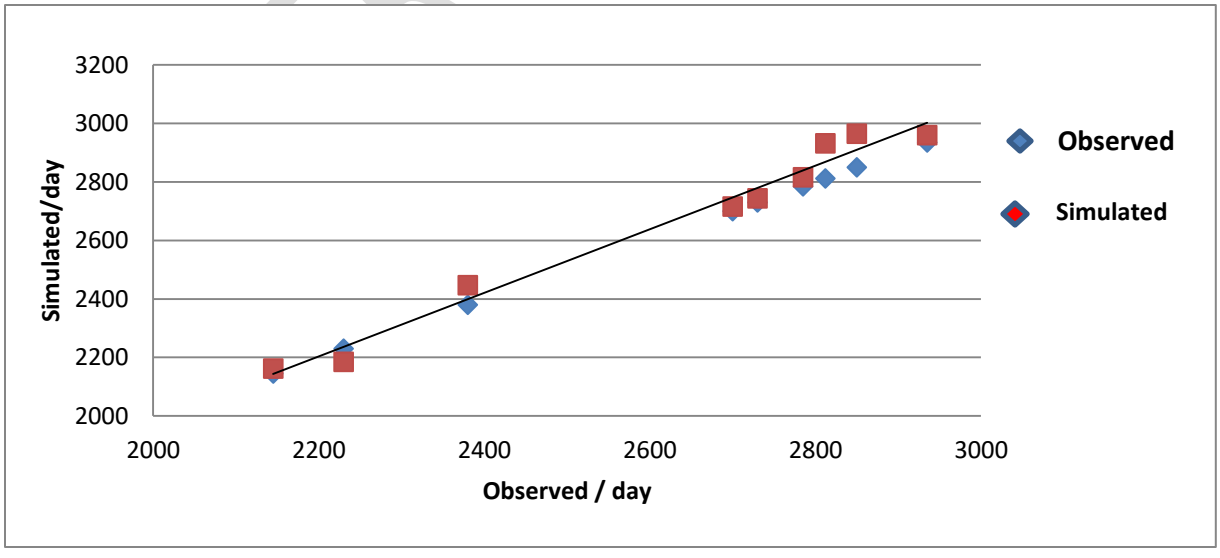

Fig: 3 Relationship between simulated grain yield(kg/ha.) at the harvest of wheat cultivars.

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Table 4. Validation of 3 wheat varites (Kanchan, HD2967 and CG1013) for days to anthesis, days to maturity and grain yield under different growing environment, based on rabi seasion 2020-21.

	Days to anthesis				Days to maturity				Grain yield (Kg/ha)			
Variety	**Obs value**	**Sim value**	**Error (%)**	**RMSE (%)**	**Obs value**	**Sim value**	**Error (%)**	**RMSE (%)**	**Obs value**	**Sim value**	**Error (%)**	**RMSE (%)**
V1												
Kanchan	70	72	2.8	1.41	106	110	3.6	2.83	2850	2965	3.9	81.32
	69	71	2.8	1.41	101	108	6.5	4.95	2785	2816	1.1	21.92
	68	71	4.2	2.12	96	105	8.6	6.36	2700	2716	0.6	11.31
V2												
HD2967	72	73	1.4	0.71	110	113	2.7	2.12	2380	2447	2.7	47.38
	70	73	4.1	2.12	108	110	1.8	1.41	2230	2185	-2.1	31.82
	68	72	5.6	2.83	100	108	7.4	5.66	2145	2162	0.8	12.02
V3												
CG1013	70	71	1.4	0.71	107	108	0.9	0.71	2935	2960	0.8	17.68
	68	71	4.2	2.12	101	106	4.7	3.54	2812	2932	4.1	84.85
	66	71	7.0	3.54	96	104	7.7	5.66	2730	2744	0.5	9.90

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CONCLUSIONS –

Based on the study it was concluded calibrated that model performance was good and it was able to predict the growth parameters like days to anthsis, day to maturity and grain yield with reasonably good accuracy (error% less than 10).

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