



Calibration and Validation of Cropgro (DSSAT 4.7) Model for Chickpea (*Cicer arietinum* L.) Crop in Raipur

Yogesh Janghel^{a++*} and H. V. Puranik^{a#}

^a Department of Agrometeorology, College of Agriculture Raipur, IGKV, Raipur, Chhattisgarh, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

In agriculture aspect crop simulation models play key role in developing the decision making research, technology management and policy options. It acts as useful tool to predict the growth development and production of a crop under varying soil, crop input and climatic condition. The DSSAT CROPGRO model was calibrated and validated through field experiment on chickpea crop during rabi seasons i.e. 2020-21 and 2021-22 at instructional farm Indira Gandhi Krishi Vishwavidyalaya, Raipur Chhattisgarh. The experiment was laid out in randomized block design (factorial) considering 9 treatments of two factors 3 dates of sowing (D_1 =Nov. 10, D_2 =Nov. 25, D_3 =Dec. 10) and 3 cultivars (V_1 =Vaibhav, V_2 =JG-14 and V_3 =JG-16). The results reported highest deviation percentage at anthesis days was (4.8 to 10 %) and physiological maturity was (1.7 to 5.5%) for JG-16 cultivar, whereas in seed yield the highest deviation percent was (6.2 to 9%) for Vaibhav cultivar. Similarly after validation the highest deviation percentage at anthesis days was (0 to 10.7%) for JG-16, at physiological maturity (1.8 to 3.6%) for Vaibhav and in seed yield (2.4 to 9.5%) for JG-16.

⁺⁺ Ph. D.;

[#] Scientist;

*Corresponding author: E-mail: janghelyogesh59@gmail.com;

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1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a diploid species having 16 chromosomes and belongs to the family leguminosae. It is the third most important pulse crop in the world after dry bean and peas whereas, in India it is first most important pulse crop. Chickpea is a cheap and important source of protein for those people who cannot afford animal protein or who are largely vegetarian [1,2,3]. Crop growth models are computer software programs that can simulate daily growth and development of crops. These models have been developed by scientists worldwide over the last 40 years. They play an important role in scientific research and resource management and have been used to help students to understand, observe and experiment with crop systems [4]. The DSSAT is a software package integrating the effects of soil, crop phenotype, weather and management options that allows users to simulate results by conducting experiments in a minutes on a computer. The DSAAT was utilized to simulate multi-year outcomes of crop management strategies for different crops at any location in the world. At present DSSAT v 4.7 contains models of 32 crops. Chick pea CROPGRO is a widely used crop simulation model [5,3,6]. Calibration is adjustment of the system parameters so that simulated results reach a predetermined level, usually that of an observation. It is necessary when adapting an existing application model to a new environment. Both the comprehensive and simplified crop models have technical problems, but they generally can provide reasonably good predictions, especially when the model is properly calibrated for a region [7]. Validation is the comparison of the results against observed data; ideally, the observed data are not the same data used for model estimation or calibration. A practical model should be rigorously validated under widely differing environmental conditions to evaluate its accuracy on overall yield predictions, the results from the validation process are used to refine the model.

Hence this work was done with the objective to calibrate and validate Chick pea CROPGRO model using the experimental data collected from the field experiment conducted in Raipur.

2. METHODOLOGY

To evaluate the model, field experiments were conducted on chickpea crop during rabi seasons of 2020-21 and 2021-22 at instructional farm Indira Gandhi Krishi Vishwavidyalaya, Raipur Chhattisgarh which located at latitude of 21.16' N, longitudes 81.36' E and altitude 289.5 m above mean sea level. The experiment was laid out in randomized block design (factorial) with three replications, considering 9 treatments of two factors (3 dates of sowing (D_1 =Nov. 10, D_2 =Nov. 25, D_3 =Dec. 10) and 3 cultivars (V_1 =Vaibhav, V_2 =JG-14 and V_3 =JG-16). Yield and phenological stages like days taken to anthesis, Days taken to physiological maturity and seed yield were used for calibration and validation of the DSSAT model. The daily weather data viz. maximum, minimum temperature, rainfall bright sunshine hours etc. were collected from Agrometeorological observatory Raipur, C.G. The soil physical and chemical data were collected for the study area. The cultivar specific genetic coefficients of every chickpea cultivar (Vaibhav, JG-14 and JG-16) were derived with a close match between observed and simulated phenology, growth and yield. The model was calibrated for phenology, growth and between yield used experimental data during 2020-21 and validated from the data generated during 2021-22. For the evaluation of the model performance different statistical measure like R^2 , RMSE and error % were used.

3. RESULTS AND DISCUSSION

3.1 Calibration of DSSAT 4.7 Model for Different Cultivars of Chickpea Crop

DSSAT 4.7 model was calibrated for the Raipur center with the help of actual or measured data and simulated data of the year 2020-21 for the calibration of DSSAT CROPGRO model and error statistics calculated for the same were represented in Table 1.

3.2 Days Taken to Anthesis

The deviation between simulated and observed anthesis days were recorded 0 to +3 days by Vaibhav and JG-14 and +3 to +6 days by JG-16 respectively. The Root mean square error (RMSE) between the actual and predicted

anthesis days was also found same for Vaibhav & JG- 14 i.e. 0, 2 and 3 days while it was reported 6, 4 and 6 days for JG-16. Similarly, deviation % ranges between 0 to 5.2 %, 0 to 5.3 % and 4.8 to 10 % for Vaibhav, JG-14 and JG-16, respectively. R² value 0.52 was found for anthesis days (Fig.1).

3.3 Days for Physiological Maturity

The variation of deviation for Physiological maturity was 0 to +5 days for Vaibhav, 0 to +5 days for JG-14 and +2 to +6 days for JG-16. The RMSE was found 0, 2 and 5 for days for Vaibhav&JG-14 and 2, 4 and 6 days for JG-16. The deviation % of physiological maturity were found 0 to 4.7% for Vaibhav & JG-14 and 1.7 to

5.5% for JG-16. Coefficient of determination (R²) of physiological maturity was observed 0.6219 (Fig.2).

3.4 Seed Yield (kg ha⁻¹)

The grain yield simulated by the model and observed yield from the field deviated from+81 to +84 Kg/ha, for Vaibhav, +7 to +43 Kg/ha for JG-14 and +4 to +46 Kg/ha for JG-16. The RMSE for grain yield were obtained 81, 84 and 81 Kg/ha for Vaibhav, 43, 21 and 7 Kg/ha for JG-14 and 46, 34 and 4 Kg/ha for JG-16, respectively. The deviation % varied between 6.2 to 9% for Vaibhav, 0.6 to 3.2% for JG-14 and 0.5 to 4.1% for JG-16.The R² was found 0.9671 (Fig.3).

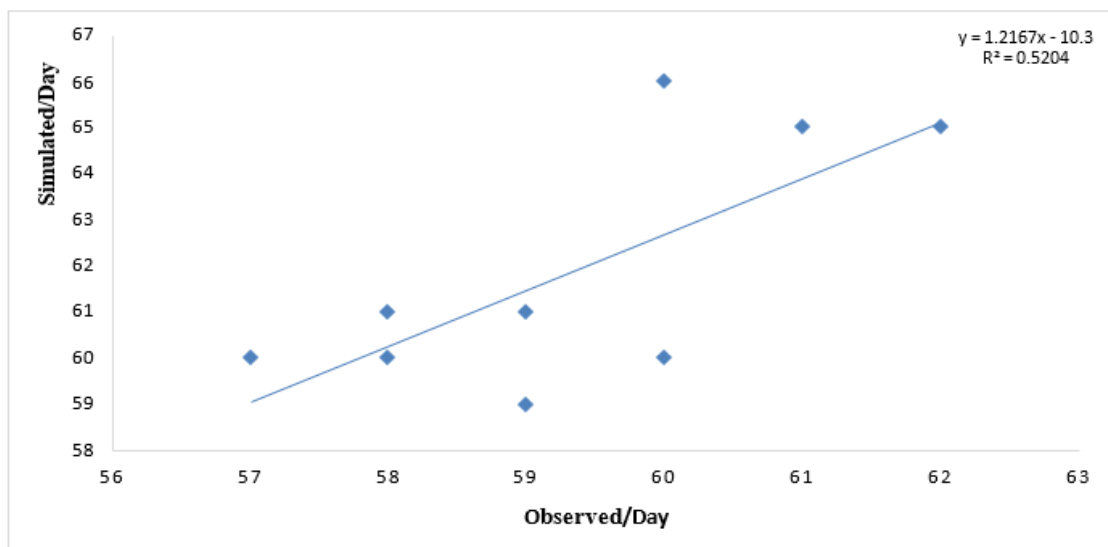


Fig. 1. Simulated and observed anthesis days calibration

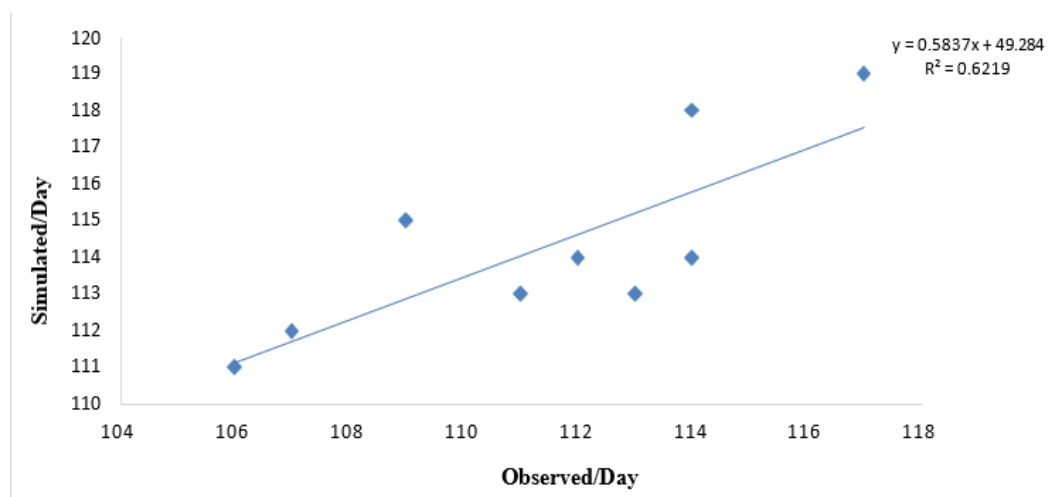


Fig. 2. Observed and simulated physiological maturity days calibration

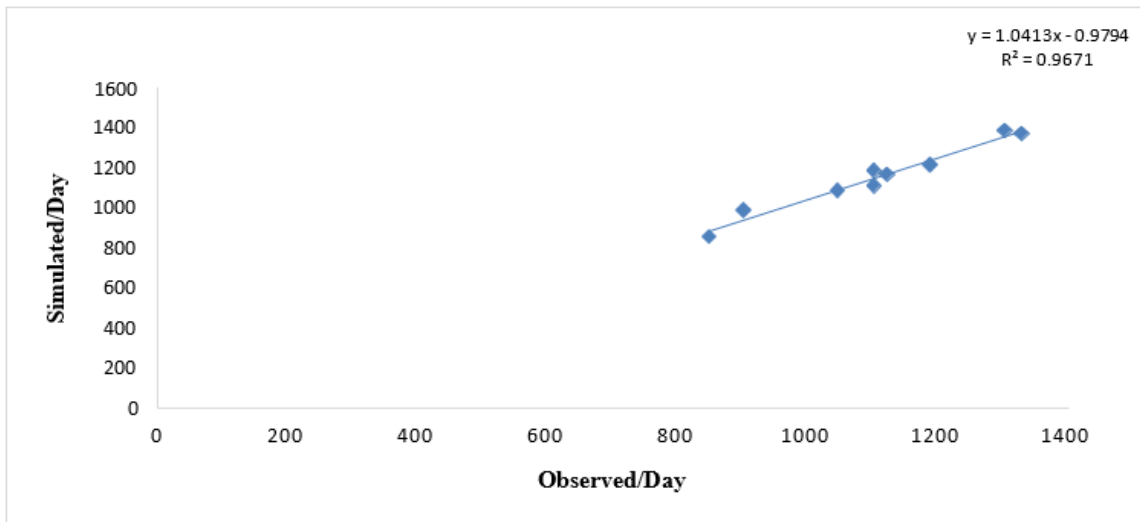


Fig. 3. Observed and simulated grain yield (kg/h) during calibration

3.5 Validation of the DSSAT CROPGRO Model for Different Cultivars of Chickpea Crop

3.5.1 Days taken to anthesis

Data pertaining to validation of simulated days taken to anthesis from observed in chickpea cultivars sown under different sowing date for the year 2021-22 were presented in Table 2 and error percentage and root mean square error was worked out between simulated & observed days taken to anthesis of chickpea.

It is evident from the data presented in Table 2. 2 deviation between simulated and observed anthesis days were recorded 0 to +6 days, 0 to +5 days and 0 to +6 days for Vaibhav, JG-14 and JG-16, respectively. The RMSE obtained between the actual and predicted anthesis days was found 0, 3 and 6 days for Vaibhav, 0, 3 and 5 days for JG-14 and 0, 4 and 6 days for JG16, respectively. Similarly, deviation % ranges between 0 to 10.5%, 0 to 8.8% and 0 to 10.7% for Vaibhav, JG-14 and JG-16, respectively. The R² value was found 0.6433 (Fig.4).#

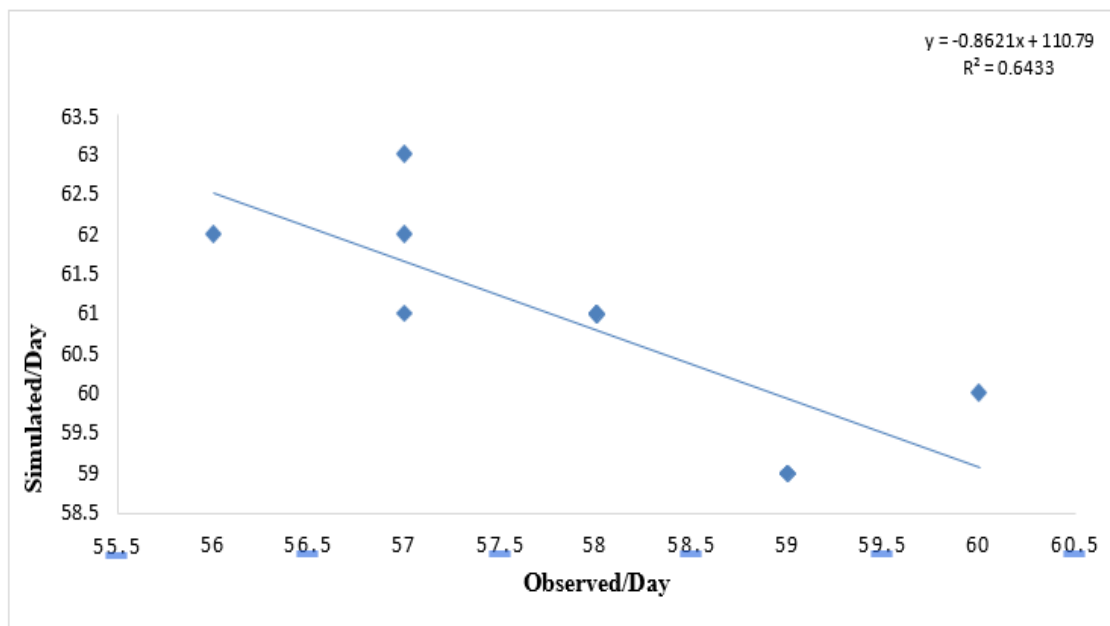


Fig. 4. Observed and simulated anthesis days during validation

Table 1. Calibration of DSSAT CROPGRO model for 3 cultivars (V1-Vaibhav, V2-JG-14 and V3-JG-16) of chickpea crop under different growing environment, during *rabi* season 2020-21

Cultivar	Days to anthesis				Days to maturity				Grain yield (Kg/ha)			
	O	S	E (%)	RMSE	O	S	E (%)	RMSE	O	S	E (%)	RMSE
V1	60	60	0.0	0	114	114	0.0	0	1301	1382	6.2	81
	59	61	3.4	2	112	114	1.8	2	1100	1184	7.6	84
	58	61	5.2	3	107	112	4.7	5	901	982	9.0	81
V2	59	59	0.0	0	113	113	0.0	0	1327	1370	3.2	43
	58	60	3.4	2	111	113	1.8	2	1187	1208	1.8	21
	57	60	5.3	3	106	111	4.7	5	1100	1107	0.6	7
V3	62	65	4.8	3	117	119	1.7	2	1120	1166	4.1	46
	61	65	6.6	4	114	118	3.5	4	1045	1079	3.3	34
	60	66	10.0	6	109	115	5.5	6	848	852	0.5	4

Table 2. Validation of 3 chickpea cultivars (V1-Vaibhav, V2-JG-14 and V3-JG-16) for days to anthesis, days to first pod formation, days to maturity and grain yield under different growing environment, based on *rabi* season 2021-22

Cultivar	Days to anthesis				Days to maturity				Grain yield (Kg/ha)			
	O	S	E (%)	RMSE	O	S	E (%)	RMSE	O	S	E (%)	RMSE
V1	60	60	0	0	112	114	1.8	2	1719	1729	0.6	10
	58	61	5.2	3	111	115	3.6	4	1502	1558	3.7	56
	57	63	10.5	6	108	110	1.9	2	1207	1225	1.5	18
V2	59	59	0.0	0	113	113	0.0	0	1545	1590	2.9	45
	58	61	5.2	3	110	114	3.6	4	1369	1440	5.2	71
	57	62	8.8	5	107	111	3.7	4	1036	1060	2.3	24
V3	59	59	0.0	0	113	113	0.0	0	1457	1492	2.4	35
	57	61	7.0	4	112	114	1.8	2	1454	1490	2.5	36
	56	62	10.7	6	107	111	3.7	4	1001	1096	9.5	95

3.5.2 Days taken to physiological maturity

The difference between simulated and observed physiological maturity dates was +2 to +4 days for Vaibhav and 0 to +4 days for JG-14 & JG-16, respectively. The RMSE values varied from 2, 4 and 2 days for Vaibhav, 0, 4 and 4 days for JG-14 and 0, 2 and 4 days for JG-16 respectively. The percent of error between observed and simulated physiological maturity was observed 1.8 to 3.6% for Vaibhav, 0 to 3.7% for JG-14 & JG-16, respectively. The coefficient of determination R^2 was recorded 0.5381 (Fig.5).

3.5.3 Seed yield (kg ha⁻¹)

Simulated and observed grain yield of chickpea cultivars were presented in Table 2. The difference between the simulated and observed grain yield ranges from +10 to +56 kg/ha for Vaibhav, +24 to +71 kg/ha for JG-14 and +35 to +95 Kg/ha for JG-16, respectively. The RMSE was 10, 56 and 18 Kg/ ha for Vaibhav, 75, 71 and 24 Kg/ ha for JG-14 and 35, 36 and 95

Kg/ha for JG-16, respectively. The percent of error between observed and simulated seed yield was observed 0.6 to 3.7% for Vaibhav, 2.3 to 5.2% for JG-14 and 2.4 to 9.5% for JG-16 respectively. The R^2 value was found value of 0.9882 (Fig.6). The calibration and validation of the crop growth model are integral to their development, evaluation and application. This process helps to ensure that the models are reliable, accurate and applicable across different conditions.

Two statistics were used to evaluate the model performances. Root Mean Square Error (RMSE) and d-stat index. Willmott [8] stated that the d-stat index value should approach unity and the RMSE should approach zero for good performance of the model. Hence the model was able to predict phenological stages and yield. When we compare R^2 values, model was able to predict yield in more correlation with the observed value compared with the phenological stages. According to Vysakh *et*

a). [9] the percentage deviation between observed and predicted values within 10 per cent indicates good performance of the model. In this study the error percentage calculated was below 10 in most of the cases and hence the model showed a good performances.

Patil and Patel, 2017, calibrated and validated the DSSAT CROPGRO model by using field

experimental data of two consecutive *rabi* seasons 2014-15 and 2015-16 at Anand, Gujarat. They found that the error % between measured and observed for all the parameters was found below ± 10 % error. The model could be used to predict the seed yield accurately under different management conditions. Hence, the CROPGRO model can be used to simulate the phenology and yield of chickpea.

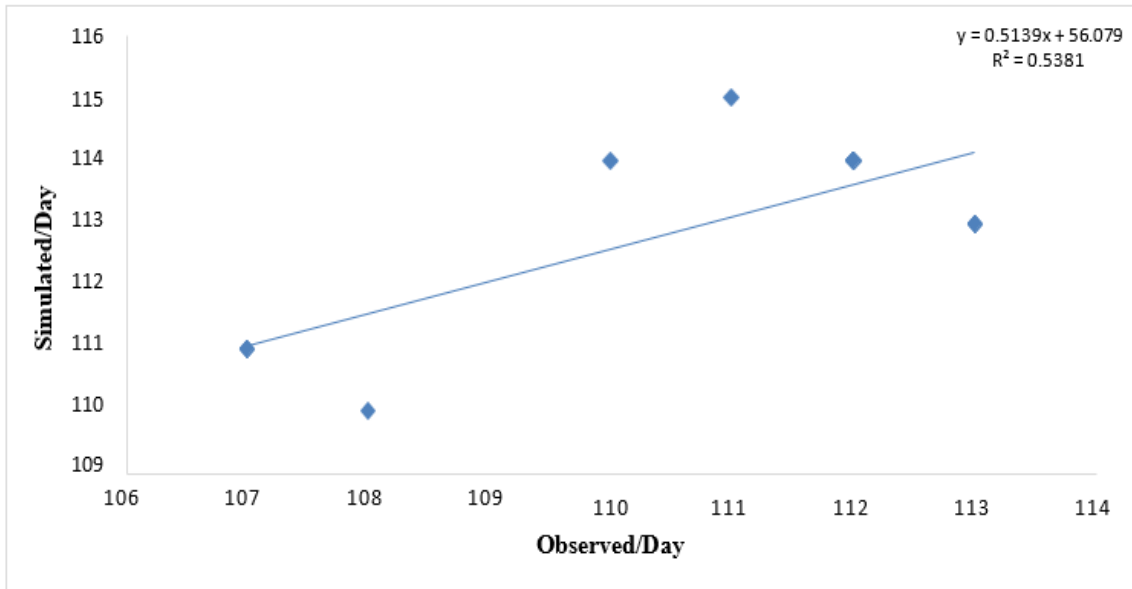


Fig. 5. Observed and simulated values of physiological maturity day during validation

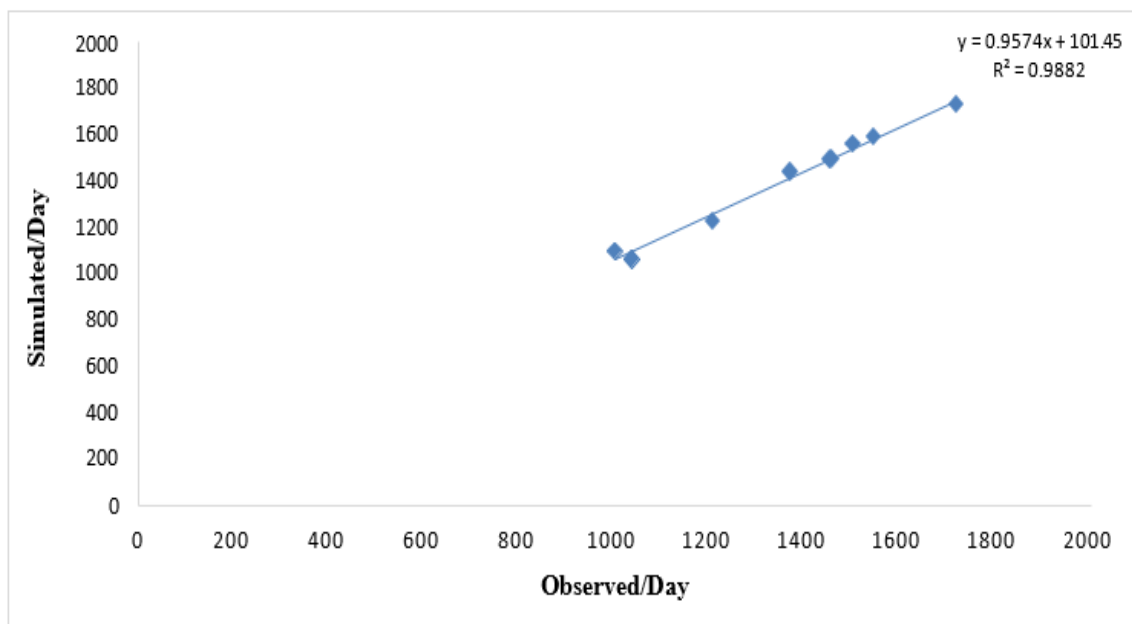


Fig. 6. Observed and simulated grain yield (kg/ha) during validation

4. CONCLUSION

The validation outcome of DSSAT CROPGRO model revealed that the model satisfactorily simulated the yield attributes of observed data and can be adopted for prediction of crop growth phenology and grain yield of chickpea crop Raipur district. Result can be used for farmers at regional level and for agro-advisory program.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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