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Calibration, validation and sensitivity analysis of CROPGRO model for mung bean and Indian bean

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Abstract
Climate change is a global issue with wide-ranging impacts, and tropical areas are particularly vulnerable to its effects. Due to India located in a tropical region, it's become susceptible to the impacts of climate change. As a result, studying the effects of climate change on crop yields in India has become crucial. It is imperative to find viable solutions to mitigate these impacts to ensure food security for the population. The first objective of study aimed to calibrate and validate the CROPGRO model for mung bean and Indian bean. The second objective of this study aim to generate the future climatic data under different RCPs scenarios and assess the climate change impact on mung bean and Indian bean yield. The projected climate change data was generated by using general circulation model GFLD-CM3 under RCPs scenarios for years 2035, 2065, and 2095. The generated data was used to assess the impact of climate change on the yield of mung bean and Indian bean by using a calibrated and validated CROPGRO model. The average percent error for phenology and yields of mung bean and Indian bean has remained below 10%, which indicated the least difference between simulated and observed values. The sensitivity of the CROPGRO model showed that the yield of both crops declined under all RCPs scenarios. The maximum yield was decreased under the RCP 8.5 scenario, mung bean yield decreased up to -70%, and Indian bean yield decreased up to -23.6% in the year 2095 because the average temperature of this year will increase up to 4.5°C from baseline temperature.

Keywords: Crop modeling, climate change, DSSAT, GCM, model calibration and model validation

Introduction
Crop models were successfully used to assess the impact of climate change on green gram productivity (Virani *et al*., 2022) [8], yield gap analysis of mung bean in a given agroclimatic zone (Kumbar *et al.*, 2020) [4] or assisting in the selection of suitable cultivars for specific regions and environments, forecasting yield and describing the phenological behaviour of crops (Kumar *et al*., 2014) [3], models enable the evaluation of the risk associated with different production strategies, policy and decision support and crop management optimization. Before using any crop model, its required proper calibration and validation. Once model is properly validated, it can be used for various application (Hadiya *et al.*, 2017) [1] which are mention above. Calibration of the model is an adjustment of genetic coefficients of cultivars so the model can simulate value near the observed value. Validation of the model is a comparison between simulated and observed values to determine the accuracy level of the model. A sensitivity analysis of the model was carried out to explore the behaviour of the model for different values of input parameters. The model is considered to be sensitive to a particular set of input parameters when the output values of the model change significantly when the values of the input parameters are changed slightly. An attempt was made in this study to calibrate and validate the CROPGRO model for mung bean and Indian bean to simulate phenology and yield under ideal conditions as well as under various RCPs (RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.0).

Materials and Methods
The field experiment was conducted during the *rabi* season 2021-22 at Agronomy farm, NAU, Navsari, India, situated at latitude 20°57' N, longitude 72°52' E, and at an altitude of 12 m above mean sea level. Model calibration is an adjustment of the cultivar's genetic coefficient so that the model simulated data matches with observed data. After preparing the weather, soil, management, and experimental file, the genetic coefficients of mung bean and Indian bean cultivars were estimated by the inbuilt program GLUE genetics coefficient estimator.

The GLUE tool first fixed the phenological coefficients (P) and in subsequent steps fixed the growth coefficients (G) and in the last steps, other coefficients (N) were fixed (Silawat *et al.*, 2016) [7]. Calibration of the model was done using based on cultivars data for two years (2019 and 2020) obtained from the field experiments at Mega seed Pulses and Castor Research Unit, Navsari. The field experiment data for the year 2021-22 was used for model validation.

The possible effect of climate change on mung bean and Indian bean yield was assessed through sensitivity analysis of the CROPGRO model under different future RCPs (Representative Concentration Pathways) scenarios. The daily weather (solar radiation, rainfall, maximum and minimum temperature) data from years 2021 to 2095 under different RCPs scenarios were generated by using the Mark Sim @ DSSAT weather generator (http://gisweb.ciat.cgiar.org/MarkSimGCM/) for the Navsari region using the GFDL-CM3 general circulation model (GCM). The daily weather data of 10 years (2010 to 2020) on solar radiation, temperature and rainfall under different RCPs scenarios were used as baseline data for assessment of climate change impact in future years of 2035, 2065 and 2095 under RCP 2.6, 4.5, 6.0 and 8.5 scenarios.

Results and Discussion

Calibration and derivation of genetic coefficients: The genetic coefficients of mung bean and Indian bean cultivars are not provided in the CROPGRO model. The GLUE tool estimates the genetic coefficient of cultivars based on experimental data from 2019 and 2020. The genetic coefficients were estimated after multiple runs of a GLUE coefficient estimator. Table 1 and Table 2 show values of both, original coefficients with calibrated coefficients.

Table 1: Calibrated genetic coefficients of mung bean cultivars

Parameters	Description of genetics coefficients	Original genetic coefficient (VAR# Andean Habit 4)	Calibrated genotype coefficients		
			CO-4	GBM-1	GM-7
Ecotype		Andind	Andind	Andind	Andind
EM- FL (P)	Time between plant emergence and flower appearance (R1)	34.0	31.0	34.0	27.0
FL-SD (P)	Time between first flower and first seed (R5) (Photothermal days)	9.0	13.0	13.0	9.0
FL-SH (N)	Time between first flower and first pod (R3) (photothermal days)	5.0	5.0	5.0	5.0
FL-LF (N)	Time between first flower (R1) and end of leaf expansion	34.0	29.0	31.0	26.0
SD- PM (P)	Time between first seed (R5) and physiological maturity (R7) (Photothermal days)	25.00	21.50	23.0	18.0
LFMAX (N)	Maximum leaf photosynthesis rate at 30 °C, 350 vpm CO_2, and high light ($mgCO_2/m^2$-s)	0.98	0.98	0.98	0.98
SIZLF (G)	Maximum size of full leaf (three leaflets) (cm^2)	133.0	133.0	133.0	150.0
WTPSD (G)	Maximum weight per seed (g)	0.650	0.360	0.240	0.350
SLAVR (G)	Specific leaf area of cultivar under standard growth conditions (cm^2/g)	320.0	250.0	250.0	300.0
SDPDV (G)	Average seed per pod under standard growing conditions (# [seed] /pod)	4.70	5.0	4.0	4.70
SFDUR (G)	Seed filling duration for pod cohort at standard growth conditions (Photothermal days)	22.0	13.0	10.0	11.0
PODUR (G)	Time required for cultivar to reach final pod load under optimal conditions (Photothermal days)	15.0	16.0	18.0	16.0

Table 2: Calibrated genetic coefficients of Indian bean cultivars

Parameters	Description of genetics coefficients	Original genetic coefficient	Calibrated genotype coefficients		
			Guj. Wal 1	Guj. Wal 2	Wal 125-36
Ecotype		CP0414	CP0414	CP0414	CP0414
CSLD (P)	Critical Short Day Length below which reproductive development progresses with no daylength effect (for short day plants) (hour)	12.80	12.50	12.50	12.50
PPSEN (P)	Slope of the relative response of development to photoperiod with time (positive for short day plants) (1/hour)	0.294	0.294	0.300	0.300
EM- FL (P)	Time between plant emergence and flower appearance (R1)	34.1	35.0	32.0	36.0
FL-SD (P)	Time between first flower and first seed (R5) (Photothermal days)	6.0	14.0	12.0	11.0
FL-SH (P)	Time between first flower and first pod (R3) (photothermal days)	5.0	8.6	7.5	7.0
SD- PM (P)	Time between first seed (R5) and physiological maturity (R7) (Photothermal days)	13.17	20.0	15.0	17.0
LFMAX (G)	Maximum leaf photosynthesis rate at 30 °C, 350 vpm CO_2, and high light ($mgCO_2/m^2$-s)	1.00	0.55	1.00	0.65
SIZLF (N)	Maximum size of full leaf (three leaflets) (cm^2)	133.0	150.0	170.0	160.0
WTPSD (G)	Maximum weight per seed (g)	0.650	0.600	0.600	0.600
SLAVR (G)	Specific leaf area of cultivar under standard growth conditions (cm^2/g)	325.0	180.0	270.0	205.0
XFRT (G)	Maximum fraction of daily growth that is partitioned into seed + shell	1.00	1.00	0.90	0.82

Model calibration and validation for Mung Bean Phenology: Simulated anthesis days and physiological maturity days were compared with observed data of mung bean cultivars (CO-4, GBM-1 and GM-7) shown in Fig. 1 (a, b). The model predicted the phenology of mungbean with an error of 8.55% of observed values. The lowest error percent error 4.4 was observed for days to physiological maturity with R^2 of 0.99 and an index of agreement of 0.95. Keeping in view that the field observed phonological dates can differ or be biased based on the personal judgment of the observers, CROPGRO model was able to do an excellent simulation of the phenology even in this situation (Patil and Patel, 2017) [6].

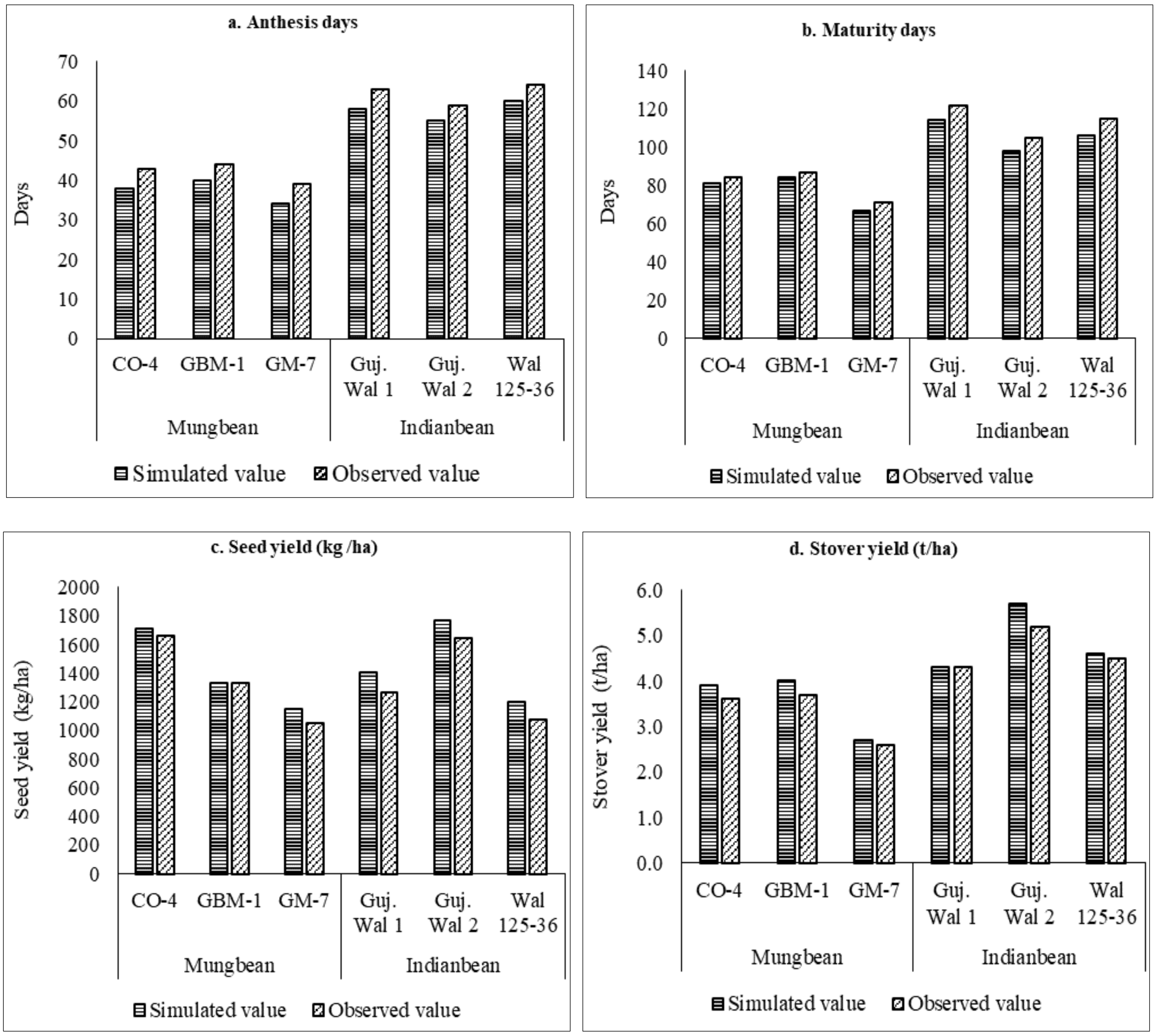

Fig 1: Mean simulated and observed (a) anthesis days, (b) maturity days, (c) seed yield, (d) stover yield of mung bean and Indian bean

Model calibration and validation for seed and stover yield of Mung Bean: Simulated seed yield and stover yield were compared with observed value of mung bean cultivars shown in Fig.1 (c, d). The simulated seed and stover yield were overestimated by the model when compared with the corresponding observed values. The percent error between observed and model simulated values for seed and stover yield has remained below 10%. The excellent simulation of seed yield and stover yield with relatively low percentage error 6.3 and 4.4, index of agreement 0.97 and 0.95, R^2 0.93 and 0.97, respectively (Table 3).

Model calibration and validation for Indian Bean Phenology

Data concerning simulated and observed days to anthesis and physiological maturity of Indian bean cultivars is presented in Fig.1 (a, b). The overall phenology of Indian bean cultivars was simulated by the model with an error of 8.30% of observed values and simulated values were underestimated by the CROPGRO model. The magnificent simulation of anthesis and maturity days with percent error 8.1 and 8.3, R^2 0.82 and 0.93, and an index of agreement 0.68 and 0.73, respectively (Table 3).

Table 3: Test criteria in the evaluation of the model concerning phenology and yield of mung bean and Indian bean

	Parameters	Days to Anthesis	Days to Physio. Maturity	Seed Yield (kg/ha)	Stover yield (t/ha)
Mung bean	RMSE	4.9	4.4	88.1	267.4
	MAPE (%)	12.7 (G)	4.4	6.3	4.4
	R^2	0.87	0.99	0.93	0.97
	Index of Agreement (D)	0.60	0.95	0.97	0.95
Indian bean	RMSE	4.6	8.8	105.1	304
	MAPE (%)	8.1 (E)	8.3	8.8	6.3
	R^2	0.82	0.93	0.98	0.90
	Index of Agreement (D)	0.68	0.73	0.93	0.93

Model calibration and validation for seed and stover yield of Indian Bean

The comparison of observed and simulated values of seed and stover yield of Indian bean cultivars is shown in Fig. 1 (c, d). The overall percent error, R^2, and an index of agreement between the observed and simulated value of seed and stover yield were 8.8 and 6.3, 0.98 and 0.90, 0.93 and 0.93, respectively (Table 3). The output of seed and stover yield was excellent simulated by the model with a relatively lower percentage error (<10%). The seed and stover yield were overestimated by the model for all cultivars.

Climate change and variability at Navsari

The annual projected change in climatic parameters from their baseline years (2010-2021) under the four scenarios during the years 2035, 2065 and 2095 for the Navsari region are presented in Table 4. The maximum temperature increased from 0.2 ℃ to 4.2 ℃, whereas the minimum temperature increased from 0.8 ℃ to 4.7℃. The temperature will rise more in RCP 8.5 than in RCP 4.5, 6.0 and 2.6 scenarios.

Table 4: Annual projected changes in climatic parameters from their baseline values under four scenarios during years 2035, 2065 and 2095

Years	Baseline period (2010-2021)	Representative Concentration Pathways (RCPs)			
		RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Maximum temperature (℃)					
2035	33.5	33.7	34.1	33.7	34.0
2065		34.0	35.3	34.3	35.9
2095		34.3	35.9	35.5	37.7
Minimum temperature (℃)					
2035	22.2	23.0	23.1	22.8	23.1
2065		23.5	24.1	24.0	25.1
2095		23.6	24.6	25.8	26.9
Rainfall (mm)					
2035	1693	1586	1645	1685	1650
2065		1644	1623	1688	1634
2095		1706	1743	1715	1747
Solar radiation (W m^{-2})					
2035	21.6	22.0	21.7	21.4	21.5
2065		22.0	21.9	21.5	21.9
2095		21.2	21.1	21.8	21.1

Impact of climate change on Mung Bean yield: Changes in seed yield of mung bean under future climate scenarios were evaluated by comparing them with the baseline simulated yield of the 2021 year. The effect of climate change on mung bean yield was studied for future years *i.e.*, 2035, 2065, and 2095 under different RCPs scenarios and was compared with the simulated yield of 2021 (Fig. 2). The maximum seed yield was decreased under the RCP 8.5 scenario, which ranged from -10 to -70%. The detrimental effect of climate change on yield was found in the year 2095 followed by the year 2065 under the scenario of RCP 8.5 followed by RCP 6.0 and 4.5, so the projected year 2095 (end of century) is a more vulnerable period to climate change for all scenarios. These studies show that RCP 8.5 is the most resilient scenario and RCP 2.6 is the least resilient scenario to climate change (Patel *et al.*, 2018) [5].

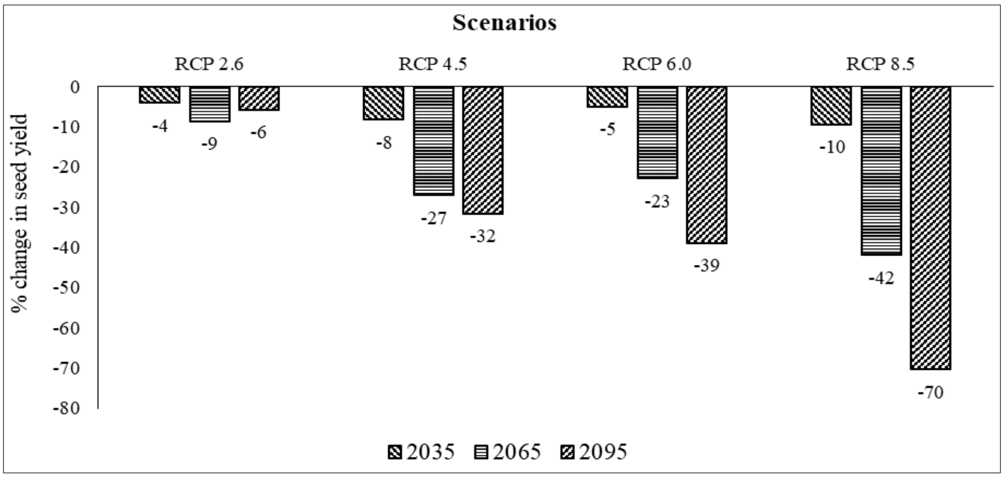

Fig 2: Change in seed yield of mung bean under different RCPs for years 2035, 2065 and 2095 as compared to that for the year 2021-22

Impact of climate change on Indian Bean yield: It has been clear that from Fig. 3, seed yield declined more under RCP 8.5 (-2.2 to -23.6%) followed by RCP 6.0 (-2.7 to -16.1%) and RCP 4.5 (-2.8 to -10.1%) scenarios for Navsari. This is due to the fact that the RCP 8.5 is a high-emission scenario with higher temperatures as compared to other scenarios (Kaur N. and Kaur P., 2019). The yield losses for the projected years 2035 and 2065 under the RCP 6.0 scenario are less compared to the RCP 4.5 scenario because for these years it will be a low emission scenario and the temperature deviations from the baseline under this scenario are less as compared to the RCP 4.5 scenario for Navsari condition.

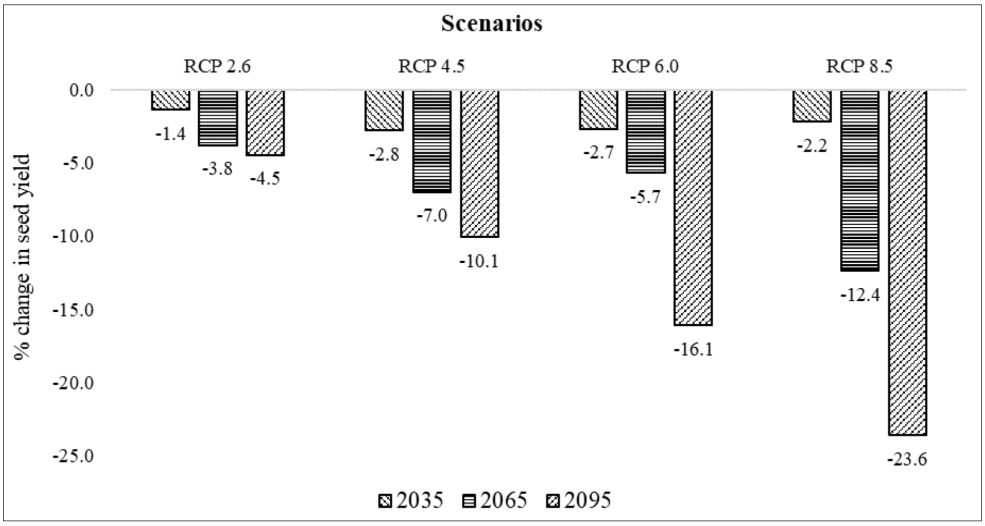

Fig 3: Change in seed yield of Indian bean under different RCPs for years 2035, 2065 and 2095 as compared to that for the year 2021-22

Conclusion

The CROPGRO model underestimated the phenology and overestimated the seed and stover yield of mung bean and Indian bean cultivars. The overall error between observed and simulated values was below 10%, which showed that the CROPGRO model was able to simulate the phenology and yield accurately for all cultivars. According to research on expected climate change, future years' temperatures may be higher than those recorded in the past. The study showed that the yield of mung and Indian beans decline in future years because it is the effect of elevated temperature. Under RCP 8.5, maximum seed yields were predicted to decline in all years, reaching an extreme level towards the end of the century.

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References

1. Hadiya NJ, Kumar N, Mote B, Thumar C, Patil D. Comparative Evaluation of WOFOST and CERES-rice Models in Simulating Yield of rice Cultivars at Navsari. Orient J Comput Sci Technol. 2017;10(1):255-259.
2. Kaur N, Kaur P. Maize yield projections under different climate change scenarios in different districts of Punjab. J Agrometeorol. 2019;21(2):154-158.
3. Kumar N, Kumar S, Nain AS. Response of CERES-wheat and CROPGRO-urd model (DSSAT model v 4.5) for Tarai region of Uttarakhand. Mausam. 2014;65:109-114.
4. Kumbar P, Patil R, Kubsad V, Naik R. Yield gap analysis of major crops grown in the northern transition zone of Karnataka. J Farm Sci. 2020;33(4):464-469.
5. Patel C, Nema AK, Singh RS, Yadav MK, Singh KK, Singh SK, *et al*. Assessment of climate change impact on wheat crop using MarkSim GCM in Varanasi, Uttar Pradesh. J Agrometeorology. 2018;20(3):216-218.
6. Patil DD, Patel HR. Calibration and validation of CROPGRO (DSSAT 4.6) model for chickpea under middle Gujarat agroclimatic region. Int. J Agric. Sci. 2017;9:4342-4344.
7. Silawat S, Agrawal K, Srivastava A. Evaluation of CHIKPGRO model in semi-arid and sub-humid climatic conditions of Madhya Pradesh. Mausam. 2016;67:599-608.
8. Virani VB, Kumar N, Mote BM, Chaudhary AR. Assessment of Projected Climate Change Impact on Green Gram Productivity through DSSAT Model under South Gujarat Environmental Condition. Int. J Environ Climate Change. 2022;12:1745-1751.