Original Research Article

Assessment of projected climate change impact on green gram productivity through DSSAT model under South Gujarat environmental condition

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ABSTRACT

An investigation on climate change's impact on green gram was conducted at Agronomy farm, NAU, Navsari, Gujarat, during the *rabi* seasons of 2021-22. The calibrated and validated DSSAT CROPGRO simulation model was used to determine the productivity of green grams under various climate change scenarios. In this experiment, the effects of CO_2 concentration, solar radiation, and maximum and minimum temperatures on green gram productivity were examined individually and in combination. According to the sensitivity of the DSSAT CROPGRO model, under the conditions of projected climate change, the best case scenario for its favo~~u~~rable impact on green gram yield was a rise in CO_2 concentration (600 ppm), along with solar radiation up to a certain level (1 unit), which may nullified the adverse effect of increases in temperature on green gram productivity.

Keywords: DSSAT, Crop mode~~l~~ling, Sensitivity analysis, Climate change, Green gram

1. INTRODUCTION

In the present century, climatic change ~~become a serious problem all over the world~~has become a serious problem worldwide. IPCC (2021) has projected an increase in global mean temperature of 1.5 ℃ was achieved before 2040, and according to Representative Concentration Pathways (RCP, 8.5), the global mean temperature is reported to increase by about 4.3 °C, and CO_2 concentration is projected to ~~increase~~ rise ~~up~~ to 1200 ppm by the end of the 21st century.

~~It is apparent that c~~Climate change will have an impact on a weather parameters~~ and these weather parameters such as temperature, solar radiation, and rainfall has~~. Weather parameters such as temperature, solar radiation, and rainfall have ~~been determining~~determined the ~~productivity of crop~~crop productivity of a given locality. Looking at the projected climate change scenario, it is necessary to assess the productivity of green gram crops ~~in relation to~~concerning expected climate change conditions. The CROPGRO module of the DSSAT crop simulation model is a very useful tool to evaluate the expected yield of the crop in relation to various projected climate change scenarios because this tool can reduce the expense and time consuming of field experimentation (Kumar *et al.,* 2017).

Dhage and Patil (2020) studied the effect of elevated temperature on green gram yield was evaluated by using the CROPGRO model. The result showed that a rise in temperature by 1-2 ℃ had a negative impact on seed yield (declined by -3.56%). The sensitivity of the CROPGRO model simulated the chickpea yield to incremental units of CO_2, resulting in a gradual increase in seed yield (Patil *et al.,* 2018).

2. MATERIALS AND METHODS

2.1 General information

The field experiment was conducted during *rabi* season 2021-22 at Agronomy farm, NAU, Navsari, India, situated at latitude 20°57' N, longitude 72°~~52'~~ 52' E, and ~~at~~ an altitude of 12 m above mean sea level. The GBM cultivar of green gram was sown on three different dates (27th October (D_1), 11th (D_2), and 26th November (D_3)). The monthly means of weather data during the crop growing season (October to February) are presented in ~~table~~ Table 1.

Table 1: Monthly mean of weather conditions during the growing season (October to March)

Month	Maximum temperature (℃)	Minimum temperature (℃)	Bright sunshine hours (hr.)	Solar radiation (MJ m^{-2} day^{-1})	Relative humidity (%) (morning)
October	33.6	17.1	9.0	19.13	73
November	33.7	18.2	7.4	15.98	69
December	29.2	14.7	6.2	13.55	86
January	28.9	14.0	7.2	15.37	91
February	31.1	13.7	9.3	20.03	78
March	36.3	17.3	8.5	20.70	67

2.2 Calibration and validation of DSSAT CROPGRO model for green gram

The first step in using the CROPGRO model to determine crop productivity under anticipated climatic circumstances is to perform model calibration and validation. The model was calibrated by using the past three years' weather, soil, and yield data of green gram and ~~calculates~~ calculating a genetic coefficient~~s~~ of *cv.* GBM-1 by GLUE genetic coefficient estimator ~~which is an inbuilt option in the model, followed by a manual method until the desired agreement made~~is an inbuilt option in the model, followed by a manual method until the desired agreement between simulated and observed values is reached. The calibrated genetic coefficient of *cv.* GBM-1 is presented in table 2. The model was validated with ~~field experimental~~experimental field data (2021-22), and the ~~accuracy of the model~~model's accuracy was tested with normalized root mean square error (nRMSE), which in our case was 8.02 percent.

Table 2: Calibrated ~~of~~ genetic coefficients of GBM-1 cultivar of green gram

Parameter	GBM-1

EM-FL (Time between emergence to flower appearance)	33.8
FL-SD (Time between first flower and first seed (R5))	18.1
FL-SH (Time between first flower and first pod (R3))	10.5
FL-LF (Time between first flower and end of leaf expansion)	13.0
SD-PM (Time between first seed and physiological maturity)	19.77
LFMAX (Maximum leaf photosynthesis rate at 30 ℃, 350 ppm CO_2 and high light)	0.99
WTPSD (Maximum weight per seed (g))	0.560
SLAVR (Specific leaf area of cultivar under standard growth conditions (cm^2/g)	130
SDPDV (Average seed per pod under standard growing condition (#[seed]/pod))	10.5
SFDUR (Seed filling duration for pod cohort at standard growth condition)	24.3
PODUR (Time required for cultivar to reach final pod load under optimal condition)	18.0
XFRT (Maximum fraction of daily growth that is partitioned to seed + shell)	1.00
THRSH (The maximum ratio of (seed/seed+shell) at maturity)	78.0
SDPRO (Fraction protein in seed (g[protein]/g [seed]))	0.240
SDLIP (Fraction oil in seed (g[oil]/g[seed]))	0.055

2.3 Climate change study through DSSAT CROPGRO model

After validati~~on CROPGRO model, sensitivity analysis (response of model to change input parameters) of~~ng the CROPGRO model, sensitivity analysis (response of the model to change input parameters) of the CROPGRO model was used to study the impact of maximum temperature, minimum temperature, bright sunshine hours, CO_2, and solar radiation on the seed yield of green gram. The simulated value of seed yield under expected climate conditions was compared with a corresponding value of ~~seed~~ yield under normal weather conditions to measure the yield variation (%) under given climatic conditions. After calibration and validation of the model, the following step ~~had been~~was used for the climate change study: (1) Open DSSAT model. (2) Open the management file~~ and select environment and go to~~, select environment, and go to the environmental modification option. (3) Add input levels of a climatic parameter that you want to see the actual climatic parameter changes up to this level. (4) Go to the treatments option and assign environmental modification as treatment. (5) Refresh the model and run it.

3. RESULTS AND DISCUSSION

3.1 Effect of temperature on seed yield

The impact of increased and decreased temperatures (±5 ℃) on seed yield variation under the different sowing dates is presented in table 3. The results showed that the increase in maximum temperature had a negative impact (yield declined from -5.1 to -49.5 %). T~~ and t~~he decrease in maximum temperature ~~had a positive impact on the seed yield (rises from 4.7 to 35.2 %) due to the fact that decrease in temperature will increas~~positively affected the seed yield (rises from 4.7 to 35.2 %) because a decrease in temperature will increase the duration of different phenological stages, which provides a much larger period for photosynthesis (Butterfield and Morison, 1992).

The sensitivity of the CROPGRO model simulated the seed yield gradually increased when the minimum temperature was decreased up to -3 ℃ (Table 3), then yield was decreased with temperature decrease because the minimum temperature goes close to the base temperature of green gram where plant growth not possible. A seed yield decreased with the minimum temperature increased up to +5 ℃ because a higher rate of respiration during the night-time was caused by the higher minimum temperature resulting in a comparatively higher loss of photosynthates (Shamim *et al.,* 2010). The ~~above-~~above-presented result was a good confirmation of the findings of Kumar *et al.* (2017) and Yadav *et al.* (2016).

3.2 Effect of CO_2 on seed yield

The sensitivity of the CROPGRO model showed the positive impact of elevated CO_2 concentration on seed yield (from 17.52 to 49.27 %) (Table 3). The rise of seed yield under the increase in the concentration of CO_2 may be due to the plant assured more entry of CO_2 in the plant system ~~and~~, resulting in the plant exhibiting ~~the~~ a higher rate of photosynthesis. However, since CO_2 is a greenhouse gas, ~~an increase in~~increasing CO_2 concentration is responsible for the rising earth's surface temperature. In this situation, a combined ~~studies~~ study of CO_2 and maximum temperature and its impact on seed yield is necessary. The results of the combined experiments showed that the seed yield dropped (from 11.87 to -7.70%) as combinedly increase CO_2 concentration and maximum temperature. It has been concluded that the seed yield rises more ~~as increase CO_2 concentration alone but seed yield was decreased with rises both CO_2 concentration and temperature~~with increased CO2 concentration alone but seed yield decreases with both CO2 concentration and temperature rises.

Table 3: % change of seed yield due to varying temperature, CO_2, and combined effect of CO_2 and maximum temperature under different sowing date

Change in climatic parameters	**% Change yield from base seed yield**		
	27/10/2021 (D_1) (1376 kg ha^{-1} base yield)	**11/11/2021 (D_2) (1449 kg ha^{-1} base yield)**	**26/11/2021 (D_3) (1461 kg ha^{-1} base yield)**
Max.T (℃)			
-5	35.2	24.3	18
-4	31	28.4	22.1
-3	20.3	18.2	15.5
-2	14.5	16.1	11.2
-1	5.6	8.7	4.7
+1	-9.4	-5.1	-10.0
+2	-20.9	-15.2	-14.3
+3	-28.7	-22.0	-26.5
+4	-40.7	-32.9	-35.5
+5	-49.5	-41.9	-45.5
Min.T (℃)			
-5	-5.6	-23.8	-26.2
-4	-0.2	-9.1	-13.0

-3	1.9	-6.0	-7.6
-2	5.4	1.3	-5.0
-1	4.7	3.3	4.0
+1	-2.9	-1.1	1.9
+2	-10.0	-8.8	-1.9
+3	-16.1	-13.5	-3.8
+4	-19.7	-22.2	-9.7
+5	-25.1	-25.9	-12.8
CO_2 concentration (Base value 380 ppm)			
450	19.1	17.5	17.5
500	30.6	27.6	27.7
550	40.6	36.9	36.9
600	49.2	44.6	44.6
CO_2 (ppm) + MaxT (℃) (Combine effect of MaxT and CO_2)			
450 + 1	8.5	11.8	5.3
500 + 2	4.8	9.9	11.0
550 + 3	2.3	8.8	2.2
600 + 4	-7.7	1.3	-3.4

3.3 Combined effect of solar radiation, temperature, and CO_2 on seed yield

The seed yield variation (%) due to the combined effect of radiation, CO_2, and temperature is presented in table 4. The results showed that at a CO_2 concentration of 600 ppm, the green gram yield could be increased to a maximum of 9.96 to 69.77 percent by either increasing radiation and temperature by ~~3~~ three units or decreasing it by ~~2~~ two units. However, at a concentration of 450 and 500 ppm, the yield was found to be increased up to 1 unit when radiation and temperature were subtracted, and then it was found to decrease with more units subtracted. The highest benefits are obtained at the level of CO_2 concentration combined with 1 unit adding in temperature and radiation. A higher CO_2 concentration (600 ppm) may ~~be able to~~ reduce the negative effects of low radiation intensity (up to -2 units) and temperature increases on seed yield. Conversely, a low level of CO_2 (450 and 500 ppm) may be able to ~~nullified~~ nullify the negative effects of low solar radiation (up to -1 units), but yield did not increase as much as it would with a higher CO_2 concentration. Our result was in good line with a finding of Pandey *et al.,* 2007.

Table 4: % change of yield due to interactive effect of solar radiation, temperature, and CO_2 under different sowing date

Change in parameters	% Change yield from base seed yield		
	27/10/2021 (D_1) (1376 kg ha^{-1} base yield)	**11/11/2021 (D_2) (1449 kg ha^{-1} base yield)**	**26/11/2021 (D_3) (1461 kg ha^{-1} base yield)**
450 ppm			
-3	-29.51	-28.85	-22.66
-2	-12.06	-9.25	-3.70

-1	2.11	5.24	5.68
+1	25.36	29.12	20.81
+2	27.11	32.23	32.92
+3	29.07	36.44	27.38
500 ppm			
-3	-23.04	-22.64	-15.74
-2	-3.85	-1.24	4.86
-1	12.06	14.63	15.13
+1	38.44	40.79	31.83
+2	39.61	44.24	44.56
+3	42.22	49.34	38.60
600 ppm			
-3	-12.50	-12.35	-4.11
-2	9.96	11.87	18.75
-1	28.20	29.88	30.60
+1	58.43	59.49	49.08
+2	59.81	63.77	62.90
+3	63.66	69.77	56.13

4. CONCLUSION

Calibrated and validated model of the DSSAT CROPGRO model is successfully used for simulating the seed yield of green grams under projected climate change scenarios. The model demonstrated that increased CO_2 concentration and ~~increased~~ solar radiation ~~had a favourable influence on~~favored crop productivity while rising temperatures ~~have~~ had a negative impact. The combined study found that increases in CO_2 concentration and maximum temperature ~~have a detrimental impact on~~affect crop productivity. In contrast, ~~whereas~~ increases in CO_2 concentration along with solar radiation have a beneficial influence because nullified the negative impact of rises in maximum temperature. Overall, the beneficial effect of projected climate change on crop productivity can be harvested when solar radiation and temperature increase by 1 unit under all levels of CO_2 concentration.

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