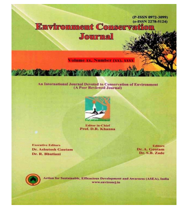
Environment Conservation Journal 24 (1):28-34, 2023

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



# Strategies to cope with warming and reduced rainfall in green gram for northern transition zone of Karnataka, India

**Sagar Dhage S** ✉

Department of Agronomy, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, Karnataka, India.

**Ravi H Patil**

Department of Agricultural meteorology, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad, Karnataka, India.

## ARTICLE INFO

Received : 28 April 2022
Revised : 27 June 2022
Accepted : 16 July 2022

Available online: 08.01.2023

**Key Words:**
Climate change
Critical stage
DSSAT
Erratic
Seasonal analysis

## ABSTRACT

**South West (SW) monsoon has become more erratic and unpredictable in the northern Transition Zone (NTZ) of Karnataka and in the coming decades this will continue further with warming. To cope with change in climate, agronomic adaptation strategies (optimum sowing window and application of irrigation at critical stages) are required to maintain higher yields of greengram. As a result, the DSSAT model was used to investigate the influence of climate change on greengram. The study included a combination of two temperature (+1 and +2 °C) and two reduced rainfall (-10 and -20 %) scenarios in comparison with the baseline scenario (i.e., current climate). These scenarios were built for 32 years using historical weather data from 1985-2016. With regard to adaptation strategies, six dates of sowing; starting from June 1$^{st}$ week to July 2$^{nd}$ week at a weekly interval and four irrigation treatments each of 60 mm; one at pre-flowering stage, one at pod formation stage, one each at pre-flowering and pod formation stages, and no irrigation (rainfed) were included. Between sowing dates, the model's simulation of average grain yield across 32 years revealed that, 3$^{rd}$ (513 kg ha$^{-1}$) and 4$^{th}$ (508 kg ha$^{-1}$) week of June were found to be optimum under future climate. Irrigation at any of the critical stages increased the yield, but largest positive yield response was replicated with two irrigations: one at pre-flowering and the other during the pod formation stage (556 kg ha$^{-1}$). This study clearly showed that under future climates of 1 to 2 ℃ warming with reduced rainfall scenarios (-10 % & -20 %), sowing on 3$^{rd}$ and 4$^{th}$ week of June is best one, providing two irrigations (60 mm each) one at pre-flowering and the other at pod formation stage would more than compensate the loss in yield projected under changing climates in coming decades.**

## Introduction

Greengram (*Vigna radiata* L. Wilczek) is India's most widely produced and valuable leguminous crop after chickpea and pigeonpea. In India, it is cultivated on an area of about 34.55 lakh ha with production of 16.11 lakh tons at a productivity of 466 kg/ha. In Karnataka, it is cultivated on an area of about 3.97 lakh ha with a production of 1.28 lakh tonnes and productivity of 275 kg/ha (Anon., 2018). The average productivity of greengram at national level is much higher compared to that of Karnataka. This might be due to the fact that most of greengram area in Karnataka lies in north interior districts, which are highly vulnerable to crop failure due to low and erratic rainfall. With climate change the SW monsoon has become more erratic and unpredictable in Northern Transition Zone (NTZ) of Karnataka as well. This is exposing the *kharif* crops, including greengram, to moisture stress either due to extended dry periods or low rainfall at critical stages, thus not only affecting the productivity, but has increased the risk of crop failure. Agronomic adaptation strategies are required to cope with such situations so that higher yields are harvested even under future climates. Among them, choosing optimum sowing window and applying irrigation at critical stages are the two

**Corresponding author E-mail:** *sagardhage013@gmail.com*
**Doi:https://doi.org/10.36953/ECJ.12562354**

important agronomic adaptation strategies. Moisture stress during crop growth affects productivity of all crops including greengram. Therefore, critical crop growth phases must synchronize with water availability to get maximum seed yield (Monteith, 1986). Therefore, this study was taken up to optimize sowing window and irrigation timing to cope with future projected climates.

## Material and Methods

### Description of the Study Area

A field experiment on greengram was done to collect data for modeling during *kharif* 2016 and 2018 under AICRP on MULLaRP at Main Agricultural Research Station, Dharwad, located at $15^0$ 26' North latitude, $75^0$ 07' East longitude and at an altitude of 678 m above mean sea level (MSL). This research station falls under the Northern Transitional Zone (NTZ) No-8 of Karnataka. The average annual rainfall from 1985 to 2016 period (32 ears) was 722.80 mm. The experimental site's soil was deep black clay with pH 7.61, EC 0.51 dS $m^{-1}$, organic carbon content 0.59 %, available N 225.0 kg/ha, $P_2O_5$ 19 kg/ha and $K_2O$ 322 kg/ha, and a total profile depth of 180 cm.

### Source and type of experimental data

For model calibration and evaluation, data on phenology of DGGV-2 variety *i.e.*, days to flowering, physiological maturity, grain yield, total above ground biomass and seed weight were collected. The data on layer wise soil profile was us ed to build soil module, daily weather data (Tmax, Tmin, rainfall, solar radiation) for the experiment p eriod (2016 and 2018) was used to build weather m odule, crop management and resource input data for both the years was used to build experiment file (X file), and the data on phenology, yield attributes a nd yield collected during both the years of experiment were used to build time-series (T-file) and end-of-season (A-file) files within DSSAT.

### Model calibration and validation

The genetic coefficients of DGGV-2 cultivar within DSSAT –CROPGRO model was calibrated with the data collected from *kharif* 2016 experiment (year-1) using GenCalc (Hunt *et al*., 1993), a semi-automated program embedded within DSSAT to optimize genetic coefficients, followed by expert calibration. Whereas, the data collected from *kharif* 2018 experiment (year-2) was used for evaluation of the model.

### Seasonal analysis to study the impact of adaptation strategies on climate change

For seasonal analysis study 32 years' historical weather data (1985-2016) recorded from MARS, Dharwad weather observatory was collected and this period was considered as a 'current' or baseline scenario. To study the effect of climate change on greengram, a combination of two temperature (+1 and +2°C) and two reduced rainfall (-10 and -20 %) scenarios in comparison with the baseline scenario (i.e., current climate) were created for 32 years period from 1985 to 2016. Temperature scenarios included current (actual observed weather during 1985-2016 with no change) and +1.0ºC and +2.0ºC increase in both daily maximum and minimum temperature over current. Rainfall scenarios included no change in rainfall (actual observed weather during 1985-2016), and -10 % and -20 % reduction in daily rainfall over current scenario. A total of five scenarios were created (Table 1) and the calibrated/validated DSSAT- CROPGRO model was run for 32 years to simulate response of greengram crop for each climate scenario following standard production technology developed by the UAS, Dharwad for NTZ. The mean of 32 years, its range and standard error were calculated for model simulated outputs on grain yield and were presented here.

## Results and Discussion

The most essential factor impacting a crop's adaptability and yield potential in a given place is the climate. That is why studies elsewhere have shown that more than 50 per cent of variation in the crop yield determined by climatic factors (Eghball *et al.*, 1995). Temperature and rainfall are the two most essential climatic elements that determine crop growth, development and yield. Crop phenology is mainly driven by temperature; hence crop duration is affected by changes in temperature during crop growing season, whereas, changes in rainfall results in moisture stress and affects physiological processes ultimately affecting yield.

### Response of greengram to warming and lower rainfall

Under current climate (Sce-1), the model simulated average grain yield of greengram over 32 years was 577 kg/ha. With increase in temperature by 1 and

**Table 1: Rainfall and temperature scenarios created for seasonal analysis using 32 years historical weather data (1985-2016)**

| Scenario | Scenarios | Remarks |
|---|---|---|
| Sce-1 | Control | Temperature and rainfall no change, and is the current scenario (i.e., Observed weather for the period 1985-2016) |
| Sce-2 | +1°C T & RF -10 % | Rise in daily maximum and minimum temperature by 1.0 ºC + rainfall reduced by 10 % for 1985-2016 period |
| Sce-3 | +2°C T & RF -10 % | Rise in daily maximum and minimum temperature by 2.0 ºC + rainfall reduced by 10 % for 1985-2016 period |
| Sce-4 | +1°C T & RF -20 % | Rise in daily maximum and minimum temperature by 1.0 ºC + rainfall reduced by 20 % for 1985-2016 period |
| Sce-5 | +2°C T & RF -20 % | Rise in daily maximum and minimum temperature by 2.0 ºC + rainfall reduced by 20 % for 1985-2016 period |

**(Sce-Scenario, T- temperature and RF- rainfall)**

**Table 2: Grain yield (kg ha$^{-1}$) of greengram as influenced by different sowing dates under different climate scenarios (Average of 32 years for the period 1985-2016)**

| Climate Scenarios | D1 | D2 | D3 | D4 | D5 | D6 | Mean |
|---|---|---|---|---|---|---|---|
| **BL** | 538 | 575 | 577 | 560 | 545 | 531 | 554 |
| +1°C T & RF -10 % | 483 | 508 | 532 | 525 | 519 | 485 | 509 |
| +2°C T & RF -10 % | 468 | 498 | 517 | 515 | 499 | 465 | 494 |
| +1°C T & RF -20 % | 433 | 457 | 479 | 480 | 473 | 456 | 463 |
| +2°C T & RF -20 % | 422 | 443 | 461 | 461 | 451 | 431 | 445 |
| **Mean** | 469 | 496 | 513 | 508 | 497 | 473 | |

***BL: Baseline**

2 ℃ continued with reduction in rainfall by -10 % (Sce-2 and Sce-3, respectively), the simulated yield was reduced to 532 and 517 kg ha$^{-1}$. The reduction in the yield was to the extent of 8.33 and 11.62 %, respectively compared to the yield in the current climate (Sce-1; Table 2 & Fig. 1). Similarly, under Sce-4 and Sce-5, where rainfall was reduced by 20 % with 1 and 2 ℃ increase in temperature, the yield of greengram was further reduced to 478 and 460 kg ha$^{-1}$, respectively. The reduction in yield was to an extent of 20.55 and 25.22 % for Sce-4 and Sce-5 compared to current climate (Sce-1; Table 2 & Fig. 1). This shows that, yield response to moisture stress was much more than to temperature. On average, across temperatures, 10 % reduction in rainfall reduced the yield by 10 %, whereas 20 % reduction in rainfall resulted in 22 % reduction in the yield. Exposure to higher temperatures leads to faster accumulation of thermal units, thus the maturity of crop is hastened. This is further negatively affected if crop experiences moisture stress as well, thus affecting the yield [Aggarwal *et al*. (2004); Kumar *et al*. (2007) & Adak and Chakravarthy (2010)].

**Impact of Adaptation Strategies to cope with warming and reduced rainfall**

The objective of this study was to quantify changes in greengram yields under warmer climates (+1 and +2 ℃) coupled with reduced rainfall amount (-10 and -20 %) and optimize agronomic adaptation strategies to cope with this change and sustain greengram yields in NTZ of Karnataka. Two agronomic adaptation options were explored in this study to reduce the negative effects of climate change, and the details of each are discussed below.

**Response to changes in sowing dates**

The impact of six different sowing dates, starting from June 1$^{st}$ week to July 2$^{nd}$ week at a weekly interval was used and simulated the yields of greengram for 32 years. Under current climate scenario, the model simulated the highest yield of 577 kg ha$^{-1}$ (average of 32 years) when crop was sown in 3$^{rd}$ week of June which was closely followed by the crop sown during 2$^{nd}$ week (575 kg

**Table 3: Grain yield (kg/ha) of greengram as influenced by different sowing dates and irrigation levels under different climate scenarios (Average of 32 years for the period 1985-2016)**

| Climate Scenarios | Sowing dates | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Irrigation levels | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $D_5$ | $D_6$ | Mean |
| BL | $I_0$ | 538 | 575 | 577 | 560 | 545 | 531 | 554 |
| | $I_1$ | 569 | 590 | 586 | 572 | 549 | 531 | 566 |
| | $I_2$ | 556 | 599 | 609 | 590 | 576 | 587 | 586 |
| | $I_3$ | 581 | 606 | 617 | 602 | 582 | 581 | 595 |
| | Mean | 561 | 592 | 597 | 581 | 563 | 557 | |
| +1°C T & RF -10 % | $I_0$ | 483 | 508 | 532 | 525 | 519 | 485 | 509 |
| | $I_1$ | 520 | 536 | 548 | 541 | 527 | 500 | 529 |
| | $I_2$ | 508 | 538 | 583 | 565 | 558 | 546 | 550 |
| | $I_3$ | 536 | 559 | 594 | 582 | 559 | 547 | 563 |
| | Mean | 512 | 535 | 565 | 553 | 541 | 519 | |
| +2°C T & RF -10 % | $I_0$ | 468 | 498 | 517 | 515 | 499 | 465 | 493 |
| | $I_1$ | 502 | 527 | 537 | 534 | 519 | 476 | 516 |
| | $I_2$ | 498 | 531 | 573 | 563 | 540 | 525 | 538 |
| | $I_3$ | 523 | 554 | 591 | 578 | 554 | 536 | 556 |
| | Mean | 498 | 527 | 554 | 548 | 528 | 501 | |
| +1°C T & RF -20 % | $I_0$ | 433 | 457 | 479 | 480 | 473 | 456 | 463 |
| | $I_1$ | 465 | 491 | 505 | 508 | 496 | 481 | 491 |
| | $I_2$ | 472 | 493 | 537 | 534 | 522 | 516 | 512 |
| | $I_3$ | 492 | 523 | 560 | 555 | 545 | 538 | 535 |
| | Mean | 466 | 491 | 520 | 519 | 509 | 498 | |
| +2°C T & RF -20 % | $I_0$ | 422 | 443 | 461 | 461 | 451 | 431 | 445 |
| | $I_1$ | 458 | 482 | 487 | 494 | 475 | 463 | 476 |
| | $I_2$ | 467 | 487 | 528 | 523 | 502 | 490 | 499 |
| | $I_3$ | 499 | 526 | 550 | 550 | 531 | 523 | 530 |
| | Mean | 461 | 484 | 506 | 507 | 490 | 477 | |

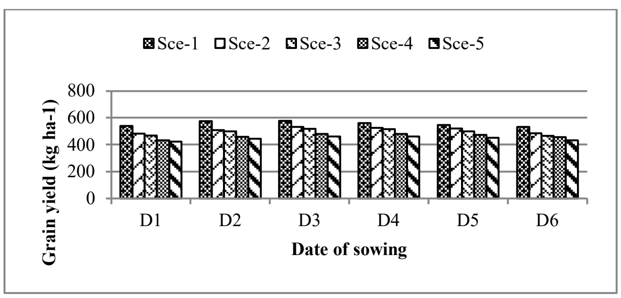



**Figure 1: Simulated grain yield of greengram as influenced by different sowing dates under different climate scenarios**

/ha) (Table 3 and Fig.3a). Under warmer climate (+1 and +2 °C) with reduced rainfall scenarios (-10 % and -20 %), across six dates of sowing, the highest yield was again simulated during 3rd week of June (497 kg/ha), but was closely followed by 4th week of June (495 kg/ha) (Table 3). With 10 % reduction in rainfall at +1 and +2 °C rise in temperature crop sown in 3rd week of June, yield was reduced by 45 and 61 kg/ha, respectively. Similarly, when the rainfall was reduced by 20 % with +1 and +2 °C rise in temperature, the yield was reduced by 91 and 109 kg/ha. This suggest that in coming decades of warmer climates with even more erratic rainfall pattern, the optimum sowing window for greengram in NTZ of Karnataka lies between 3rd and 4th week of June, a postponement by a weak. Weekly cumulative rainfall trend analysis for the month of June from 1985-2016 revealed that rainfall during first and second week of June showed much larger negative slope compared to third and fourth week (Fig. 2). This suggest that, reduction in rainfall in recent decades during first and second week of June has been

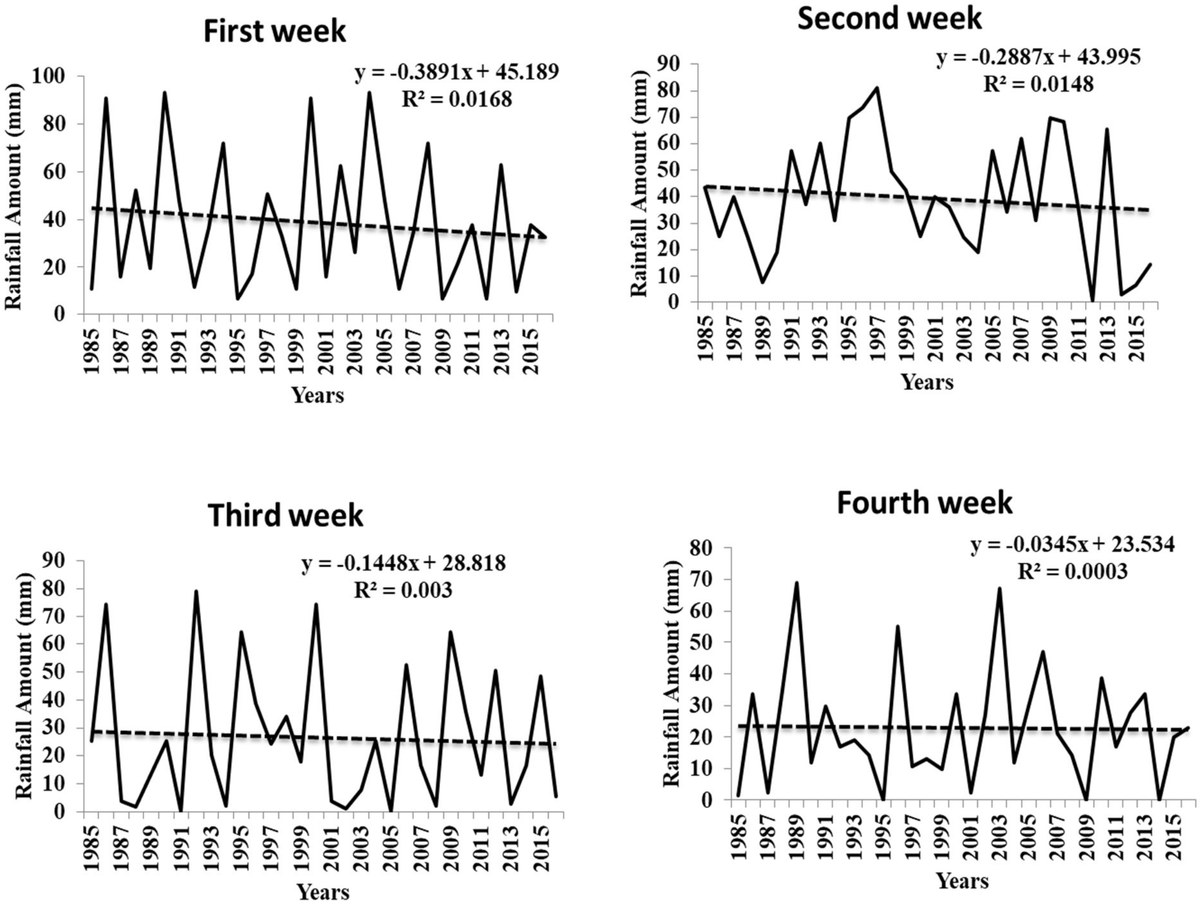



**Figure 2: Annual rainfall trend analysis for June month on yearly basis (1985-2016).**

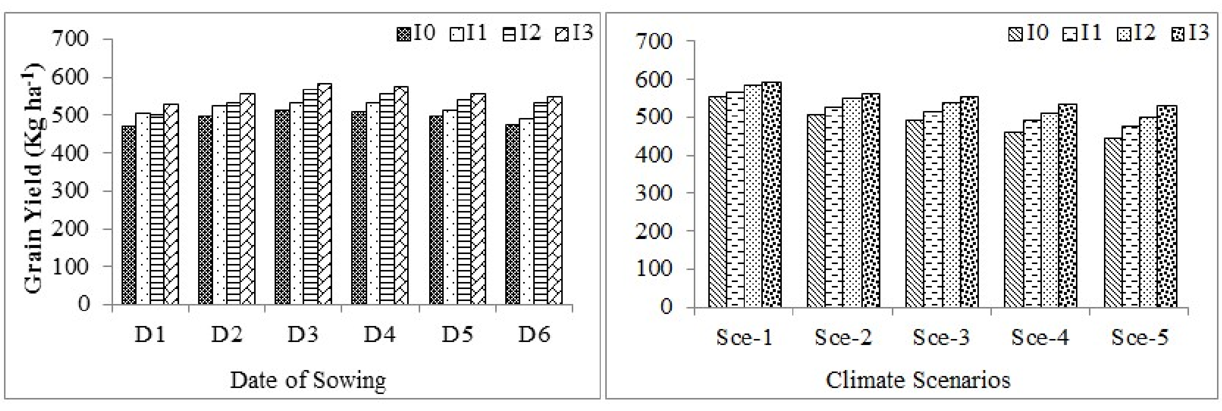



**Figure 3a: Effect of irrigation levels across dates of sowing averaged over scenarios on the yield of greengram; 3b: Effect of irrigation levels across climate scenarios averaged over dates of sowing on the yield of greengram.**

**Irrigation levels: I0: No irrigation, I1: Irrigation at pre-flowering stage, I2: Irrigation at pod formation stage & I3: Irrigation at both pre-flowering and pod formation stage.**
**Dates of Sowing: D1: June 1$^{st}$ week, D2: June 2$^{nd}$ week, D3: June 3$^{rd}$ week, D4: June 4$^{th}$ week, D5: July 1$^{st}$ week & D6: July 2$^{nd}$ week.**

much more, hence under future warmer climates this period becomes more risky to take up sowing. The optimum time of sowing ensures the complete synchrony between the vegetative and reproductive phases on one hand, and the climatic rhythm on the other, thus helping in realizing the potential yield (Singh and Dhingra, 1993). Bobade *et al*. (2018) studied the effect of sowing dates in kharif greengram and observed that 23$^{rd}$ June sowing produced maximum seed yield and which was followed by sowing on 30$^{th}$ June and 07$^{th}$ July at Parabhani, Maharashtra. This modeling study corroborates and supports these findings.

**Response to application of irrigations**

Supplemental irrigation at critical stages was simulated as one of the adaptation techniques to relieve moisture stress effects on greengram productivity under future climates, keeping enhanced variability and erraticity in SW monsoon in NTZ. For the optimum sowing time (June 3$^{rd}$ week), with 10 % reduction in rainfall at +1 and +2 °C rise in temperature with the application of single irrigation at pre-flowering stage the yield increased by 16 and 20 kg/ha, whereas, with the application of single irrigation at pod formation stage the yield increased by 51 and 56 kg/ha, respectively. However, application of two irrigation *i.e*., one at pre-flowering and other at pod formation stage enhanced the yield by 62 and 74 kg/ha, respectively compared to no irrigation in Sce-2 and Sce-3 (Table 3 and Fig. 3b). With two irrigations under Sce-2 and Sce-3 the jump in yield surpasses the yields obtained under current climate scenario (Sce-1).

For the optimum sowing time (i.e. June 3$^{rd}$ week), with 20 % reduction in rainfall at +1 and +2 °C rise in temperature with the application of one irrigation at pre-flowering stage the yield increased by 26 and 27 kg ha$^{-1}$, whereas, with the application of one irrigation at pod formation stage the yield increased by 59 and 68 kg/ha, respectively. When two irrigation were applied *i.e*., one at pre-flowering and other at pod formation stage the yield enhanced by 82 and 89 kg/ha, respectively compared to no irrigation in Sce-4 and Sce-5 (Table 3). Two irrigations at these critical stages almost compensated the loss in yield due to 20 % reduction in rainfall at +1 and +2 °C rise in temperature. Under warmer climate (+1 and +2 °C) with reduced rainfall scenarios (-10 % and -20 %), the highest yield was simulated during 3$^{rd}$ week of June (497 kg ha$^{-1}$) and was closely followed by 4$^{th}$ week of June (495 kg ha$^{-1}$), both under rainfed as well as irrigated condition. Muchow (1985) and Malik *et al*. (2006) reported that greengram is very sensitive to water stress during flowering and grain formation (Pod formation) than vegetative stage, the same is proven with this model study. This clearly showed that under future climates of +1 and +2 °C with projected lower rainfall scenarios, providing two irrigations (60 mm each) one at pre-flowering and the other at pod formation stage would more than compensate the expected loss in yield.

## Conclusion

This study showed that under current climates the highest yield of 577 kg/ha was simulated when crop was sown in 3$^{rd}$ week of June and closely followed by 2$^{nd}$ week of June (575 kg/ha). Under warmer climates (+1 and +2 °C) with reduced rainfall scenarios (-10 % and -20%), the highest yield was simulated during 3$^{rd}$ week of June (497 kg ha$^{-1}$) and was closely followed by 4$^{th}$ week of June (495 kg ha$^{-1}$). However, this reduction in yield with 10 % less rainfall is more than compensated with two irrigations (563 and 556 kg ha$^{-1}$ at +1 and +2 °C), one each at pre-flowering and other at pod formation stage. Similarly, two irrigations at these critical stages almost compensated the loss in yield due to 20 % reduction in rainfall with +1 and +2 °C rise in temperature (535 and 530 kg ha$^{-1}$). This study clearly showed that under future climates with +1 and +2 °C warming with lower rainfall scenarios, sowing of crop in 3$^{rd}$ or 4$^{th}$ week of June and providing two irrigations (60 mm each) i.e., one at pre-flowering and the other at pod formation stage would more than compensate the loss in yield projected under future climates.

## Conflict of interest

The authors declare that they have no conflict of interest.

## References


Adak, T., & Chakravarty, N. V. K. (2010). Quantifying the thermal heat requirement of Brassica in assessing biophysical parameters under semi-arid microenvironments. *International Journal of Biometeorology*, *54*(4), 365-377.

Aggarwal, P. K., Kalra, N. C., & Pathak, H. (2004). InfoCrop: A generic simulation model for annual crops in tropical environments, IARI, New Delhi.

Anonymous. (2018). www.indiastat.com

Bobade, B. R. (2018). Influence of date of sowing on kharif green gram [*Vigna radiata* (L.)] varities under varied weather conditions. *Ph.D. Thesis*, Vasantrao Naik Marathwada Krishi Vidyapeeth, parabhani.

Eghball, B., Power, J. F., Binford, G. D., Baltensperger, D. D., & Anderson, F. N. (1995). Maize temporal yield variability under long-term manure and fertilizer application: Fractal analysis. *Soil Science Society of America Journal*, *59*(5), 1360-1364.

Hunt, L. A., Pararajasingham, S., Jones, J. W., Hoogenboom, G., Imamura, D. T., & Ogoshi, R. M. (1993). GENCALC: Software to facilitate the use of crop models for analyzing field experiments. *Agronomy Journal*, *85*(5), 1090-1094.

Kumar, G., Adak, T., Chakravarty, N. V. K., Chamola, R., Katiyar, R. K., & Singh, H. B. (2007). Effect of ambient thermal on growth and yield of Brassica cultivars. *Brassica*, *9*(1-4), 47-52.

Malik, A. M. J. A. D., Waheed, A., Qadir, G. H. U. L. A. M., & Asghar, R. (2006). Interactive effects of irrigation and phosphorus on green gram (Vigna radiata L.). *Pakistan Journal of Botany*, *38*(4), 1119.

Monteith, J. L. (1986). How do crops manipulate water supply and demand?. *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences*, *316*(1537), 245-259.

Muchow, R. C. (1985). Phenology, seed yield and water use of grain legumes grown under different soil water regimes in a semi-arid tropical environment. *Field Crops Research*, *11*, 81-97.

Singh, T., & Dhingra, K.K. (1993). Response of mung (*Vigna radiata* L.) cultivars to time of sowing under south-western region of Punjab. *Journal of Research-Punjab Agricultural University (India)*, *30*: 155-159.