*Journal of Agrometeorology 20 (4) : 286-292 (December 2018)*

# Effect of intra-seasonal variation in temperature and rainfall on seed yield of pigeon pea cultivars using CROPGRO model

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## ABSTRACT

Three years (2014-15 to 2016-17) experimental data collected at Pulse Research Station, Vadodara was used to calibrate and validate the CROPGRO- pigeon pea model for three cultivars of pigeon pea (BDN 2, AGT 2 and Vaishali). The validated model was used to simulate the seed yield by changing the maximum and minimum temperature (-3$^0$ to +3$^0$C) in different months (June to January) and rainfall (-25% to +25%) during July, August and September. Results revealed that the elevated temperature had negative effect on seed yield and reduced temperature had positive effect. Among the varieties, AGT 2 was least affected by the temperatures and rainfall. Vaishali was found to be most sensitive to elevated temperature.Higher rainfall during August was beneficial on seed yield of pigeon pea. Pigeon pea sown in June was most affected due to elevated temperatures and July sown was most affected by rainfall. The effect of minimum temperature on seed yield was less than that observed with maximum temperature.

***Keywords:*** Intra-seasonal temperature, pigeon pea, CROPGRO model, climate change, rainfall

Pigeon pea [*Cajanus cajan* (L.) Millsp] commonly known as arhar, red gram or tur is a legume crop belonging to the family Fabaceae and subfamily Papilionaceae. It is an important source of protein, carbohydrates, B-group vitamins, and certain minerals (iron and iodine). India ranks first in area (74%) and production (63%) of pigeon pea in the world, where it is mostly consumed as dehusked splits or dal (Lohot *et al*. 2018). It is the second most important pulse crop next to chickpea, covering an area of around 4.42 M ha (occupying about 14.5% of area under pulses) and production of 2.86 Mt (contributing to 16% of total pulse production) and productivity of about 707 kg ha$^{-1}$. Gujarat is the fifth largest pigeon pea producing states in the country after Maharashtra, Karnataka, Madhya Pradesh and Uttar Pradesh with average yield of 1044 kg ha$^{-1}$ (Annon, 2017).

Large number of high yielding varieties have been released, but the productivity in the crop remains stagnant around 700 kg ha$^{-1}$ as compared to its potential yield (1500-3000 kgha$^{-1}$). This gap may be attributed to several biotic and abiotic factors(Kumar *et al*. 2014). Since it is mainly a rainfed crop, unfavorable rainfall (delayed, erratic, improper distribution) leads to terminal drought or heavy down pour. Non adoption of improved management practices and lack of proper research and commercial perspective for the crop influence the low productivity to a greater extent. Delayed sowings result in progressive reductions in yield due to early flowering and slow growth and subsequently results in poor pod and grain development, due to low temperature during the pod-filling stage. Cloudy weather and excessive rainfall at flowering time damage the crop to a great extent. Thus, the intra-seasonal variation in weather parameters has significant influence on seed yield of pigeon pea.

Crop simulation models have been used to study the effect of intra-seasonal variation in temperature on yield of wheat in India (Sandhu *et al.,* 2016). Patil *et al*. (2018) have reported the effect of intra-seasonal variation of temperature on tuber yield of potato in Gujarat. Yadav *et al.,* (2016) had attempted to predict the productivity of different crops under changing climatic conditions using DSSAT group of models. In this paper an attempt has been made to assess the effect of intra-seasonal variation in temperatures and rainfall on seed yield of pigeon pea in middle Gujarat using CROPGRO- pigeon pea model.

## MATERIALS AND METHODS

### *Experimental and weather data*

The data collected during three years of experimentation (2014-15, 2015-16 and 2016-17) on three cultivars ($V_1$- BDN 2, $V_2$- AGT 2 and $V_3$- Vaishali) of pigeon pea sown on five dates ($D_1$- 19$^{th}$ June, $D_2$- 1$^{st}$ July, $D_3$- 15$^{th}$

**Table 1:** Mean seed yield (kg ha$^{-1}$) of pigeon pea as affected by dates of sowing and varieties during three years (2014-15 to 2016-17)

| Treatments | 2014-15 | 2015-16 | 2016-17 | Mean |
|---|---|---|---|---|
| | | **Dates of sowing** | | |
| $D_1$ (June 19) | 1473 | 2125 | 1877 | 1825 |
| $D_2$ (July 01) | 1389 | 2093 | 1843 | 1775 |
| $D_3$ (July 15) | 1136 | 1754 | 1467 | 1452 |
| $D_4$ (July 30) | 947 | 1158 | 1324 | 1143 |
| $D_5$ (August 14) | 716 | 898 | 1098 | 904 |
| | | **Cultivars** | | |
| $V_1$ (BDN 2) | 1048 | 1465 | 1422 | 1311 |
| $V_2$ (AGT 2) | 1225 | 1740 | 1645 | 1536 |
| $V_3$ (Vaishali) | 1124 | 1612 | 1500 | 1412 |
| Mean | 1132 | 1606 | 1522 | 1420 |

July, $D_4$- 30$^{th}$ July and $D_5$- 14$^{th}$ August) and planned in split plot replicated three times, was obtained from Pulse Research Station, Anand Agricultural University, Vadodara. Seeds were sown with spacing of 60cm x 30cm and with recommended dose of fertilizer 25:50:00 NPK kg ha$^{-1}$ during all the growing seasons. The soil type of the experimental site was sandy loam a true representative soil of the region. Irrigation was applied during dry spell and plant protection measures were followed as per the scheduled package of practices. The corresponding weather data was obtained from Department of Agricultural Meteorology, Anand Agricultural University, Anand.

***CROPGRO-pigeon pea model***

The DSSAT family of CROPGRO- pigeon pea model (Hoogenboom *et al.,* 2004) was employed to simulate seed yield of pigeon pea crop. The model was calibrated and validated for different cultivars with the experimental data. The pertinent daily weather, soil and crop management data for all the sowing dates and varieties were used as input. The model was calibrated with the two years (2014-15 and 2015-16) of experimental data and validated with the third year (2016-17) data. The cultivar coefficients were estimated by repeated iteration's by running the GLUE coefficient estimator until a close match between simulated and observed seed yield was obtained.

The model performance was evaluated using test criteria viz. root mean square error (RMSE), mean absolute error (MAE), mean bias error (MBE), coefficient of determination ($R^2$) and percent error (PE) and calculated as reported by Patil and Patel (2017).

***Impact studies***

The validated CROPGRO-pigeon pea model was used to study the effect of intra seasonal variation of temperatures and rainfall on seed yield of all three varieties sown on five dates by incremental change in the monthly maximum and minimum temperatures from -3$^0$C to 3$^0$C during June to January months at 1$^0$C interval and rainfall change by ±10, ±15 and ±25 per cent during July to August. The simulated seed yields were compared with the mean observed yield and the percent departures were calculated.

## RESULTS AND DISCUSSION

***Seed yield***

The mean observed seed yield of three cultivars of pigeon pea under five dates of sowing during three years are presented in Table 1. Among different dates of sowing, the maximum seed yield (1825 kg ha$^{-1}$) was observed in first date i.e. June 19 sown pigeon pea followed by July 1 (1775 kg ha$^{-1}$), July 15 (1452 kg ha$^{-1}$), July 30 (1143 kg ha$^{-1}$) and the lowest (904 kg ha$^{-1}$) in late sown (August 14) pigeon pea. Among the varieties, the highest seed yield (1536 kg ha$^{-1}$) was observed in cultivar AGT 2 followed by Vaishali (1412 kg ha$^{-1}$). During three years of experimentation, the mean seed yield varied between 716 kg ha$^{-1}$ in 2014-15 to 2125 kg ha$^{-1}$ in 2015-16 (Table 1). Thus, it is clear that the seed yield of pigeon pea varied significantly with dates of sowing, variety and year.

***Calibration and validation***

The genetic coefficients derived for three cultivars

**Table 2:** Genotype coefficients of pigeon pea cultivars for CROPGRO-pigeon pea model

| Symbol | Description | Genotype coefficients | | |
|---|---|---|---|---|
| | | BDN2 | AGT 2 | Vaishali |
| CSDL | Critical Short Day Length below which reproductive development progresses with no day length effect (for short day plants) (hour) | 12 | 12 | 12 |
| PPSEN | Slope of the relative response of development to photoperiod with time (Positive for short day plants) (1/hour) | 0.35 | 0.35 | 0.35 |
| EM-FL | Time between plant emergence and flower appearance (R1) (photothermal days) | 71.5 | 74.3 | 67.8 |
| FL-SH | Time between first flower and first pod (R3) (photothermal days) | 10.8 | 9.7 | 10.0 |
| FL-SD | Time between first flower and first seed (R5) (photothermal days) | 24.2 | 20.2 | 25.5 |
| SD-PM | Time between first seed (R5) and physiological maturity (R7) (photothermal days) | 59.04 | 58.09 | 56.08 |
| FL-LF | Time between first flower (R1) and end of leaf expansion (photothermal days) | 56.28 | 59.01 | 50.63 |
| LFMAX | Maximum leaf photosynthesis rate at 300 C, 350 vpm $CO_2$ and high light (mg $CO_2/m^2$-s) | 1.10 | 1.10 | 1.10 |
| SLAVR | Specific leaf area of cultivar under standard growth conditions ($cm^2/g$) | 320.0 | 320.0 | 320.0 |
| SIZLE | Maximum size of full leaf (three leaflets) ($cm^2$) | 172.0 | 172.0 | 172.0 |
| XFRT | Maximum fraction of daily growth that is partitioned to seed+shell | 0.83 | 0.86 | 0.81 |
| WTPSD | Maximum weight per seed (g) | 0.11 | 0.11 | 0.14 |
| SFDUR | Seed filling duration for pod cohort at standard growth conditions (photothermal days) | 49.0 | 51.0 | 46.0 |
| SDPDV | Average seed per pod under standard growing conditions (#/pod) | 3.3 | 3.3 | 3.3 |
| PODUR | Time required for cultivar to reach final pod load under optimal conditions (photothermal days) | 21.0 | 24.0 | 22.0 |
| THRSH | Threshing percentage. The maxi. ratio of seed [seed/(seed+shell)] | 74.0 | 73.0 | 70.0 |
| SDPRO | Fraction protein in seeds [g(protein)/g(seed)] | 0.225 | 0.225 | 0.225 |
| SDLIP | Fraction oil in seed [g(oil)/g(seed)] | 0.015 | 0.015 | 0.015 |

(BDN 2, AGT 2 and Vaishali) are presented in Table 2. The observed and simulated seed yield of pigeon pea cultivar during calibration (2014-15 and 2015-16) and validation period (2016-17) are presented in Fig. 1 (a & b). The model performance evaluated by test criteria viz. RMSE (140.3), MBE (-1.07), MAE (1.07), $R^2$ (0.95) and PE (10.2) for calibration years indicated close relationship with minimum error. During validation period (Fig. 1b) also, the performance of model was quite satisfactory as indicated by the test criteria (RMSE- 120.74, MBE- 0.65, MAE- 0.65, $R^2$- 0.91 and PE- 7.4). Hence, this model can be used to simulate the seed yield of three cultivars of pigeon pea under different environments.

***Effect of temperature variations on varieties***

The effect of increase and/or decrease in maximum and minimum temperatures from -3$^0$C to +3$^0$C during crop season on seed yield of three varieties of pigeon pea are presented in Table 3. It is seen that the increase in maximum and minimum temperatures caused decrease in seed yield in all the cultivars, the magnitude varied with the cultivars, as well as the extent of increase in temperature. Conversely, the decrease in temperature caused increase in the seed yield. There was generally linear trend in yield variation due to change in temperature. With change in maximum temperature by ±1$^0$C, the change in seed yield was -5.8 to +5.5 per cent.

**Table 3**:Percent change in seed yield of pigeon pea due to change in maximum and minimum temperatures.

| Change in temperature | Maximum temperature | | | Minimum temperature | | |
|---|---|---|---|---|---|---|
| | BDN 2 | AGT 2 | Vaishali | BDN 2 | AGT 2 | Vaishali |
| -3 | 10.3 | 10.3 | 10.8 | 9.9 | 9.8 | 10.3 |
| -2 | 7.8 | 6.9 | 8.2 | 7.4 | 6.7 | 7.8 |
| -1 | 4.8 | 4.4 | 5.5 | 4.4 | 3.9 | 5.1 |
| 1 | -4.4 | -4.9 | -5.8 | -3.7 | -4.6 | -5.2 |
| 2 | -7.6 | -7.5 | -9.2 | -6.9 | -7.0 | -8.6 |
| 3 | -10.9 | -10.2 | -11.7 | -10.6 | -9.7 | -10.2 |

**Table 4**:Per cent change in seed yield of pigeon pea varieties due to change in maximum and minimum temperatures under different dates of sowing

| Change in temperature | Maximum temperature | | | | | Minimum temperature | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $D_5$ | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $D_5$ |
| -3 | 10.5 | 9.9 | 10.3 | 9.5 | 8.6 | 9.7 | 8.4 | 8.2 | 8.0 | 7.1 |
| -2 | 8.0 | 7.6 | 7.5 | 6.4 | 6.1 | 7.8 | 6.2 | 5.6 | 5.5 | 4.8 |
| -1 | 4.9 | 4.4 | 4.4 | 3.9 | 3.0 | 3.4 | 3.3 | 2.6 | 2.7 | 2.5 |
| 1 | -5.8 | -5.4 | -4.8 | -4.2 | -3.8 | -5.0 | -3.1 | -2.6 | -2.6 | -2.6 |
| 2 | -8.7 | -8.3 | -7.8 | -7.5 | -6.6 | -7.4 | -6.0 | -5.5 | -5.3 | -4.8 |
| 3 | -11.0 | -10.7 | -10.2 | -9.6 | -9.0 | -10.1 | -5.4 | -8.2 | -8.1 | -6.7 |

Where $D_1$- June 19; $D_2$- July 1; $D_3$- July 15; $D_4$- July 30 and $D_5$- August 14

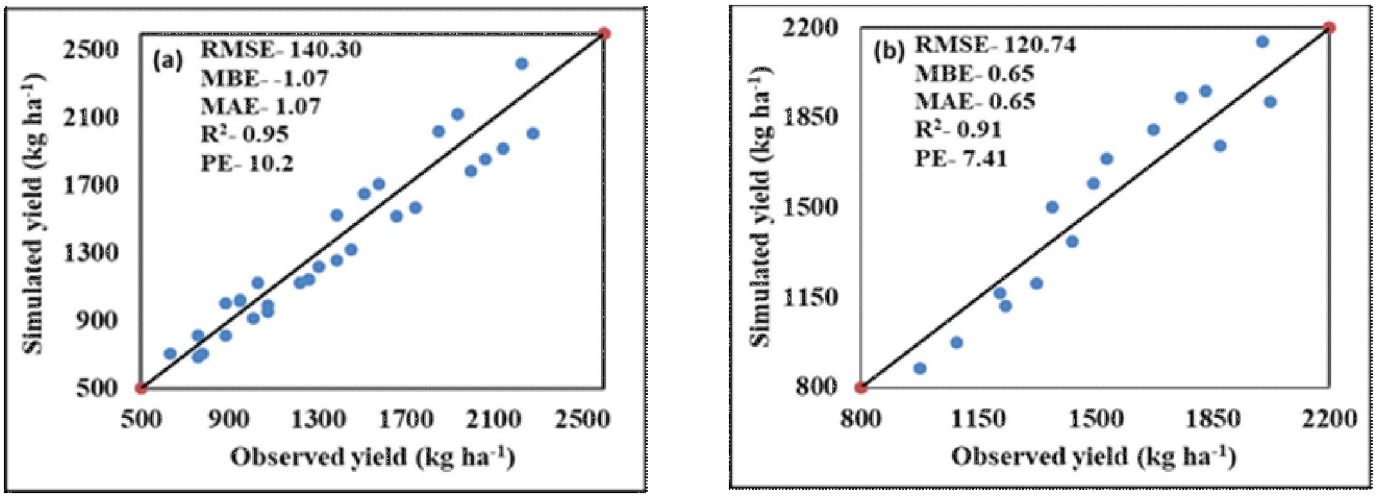


**Fig. 1:** Observed and simulated yield of pigeon pea during (a) calibration period (2014-15 and 2015-16) and (b) validation (2016-17) of CROPGRO- pigeon pea model

While with ±3$^0$C change in maximum temperature, the seed yield varied between +10.8 to -11.7 per cent. The effect of maximum temperature variation was highest in cv. Vaishali followed by BDN 2 and lowest in AGT 2. Higher temperatures during reproductive stage may have caused abnormal development of the male/ female reproductive tissues, poor production of growth regulators in sink tissues, reduced supply of photosynthates, pollen production, pollen viability, fertilization, pod/ seed-set all of which lead to poor productivity in pigeon pea (Kesava Rao *et al.*, 2013). Birthal *et al.* (2014) also reported that 1 $^0$C rise in the maximum temperature in *kharif* season reduced the yield of pigeon pea by 11-12 per cent.

The effect of minimum temperature on seed yield of

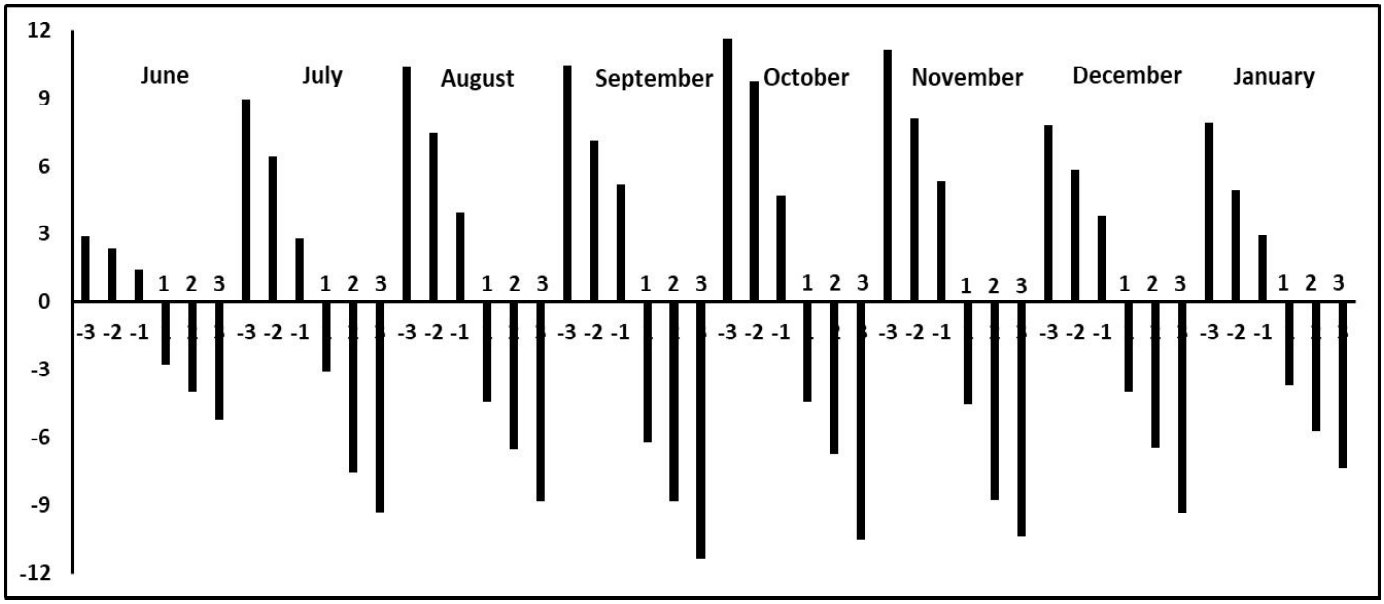


**Fig. 2:** Percent change in seed yield (%) of pigeon pea due to change in mean temperature in different months.

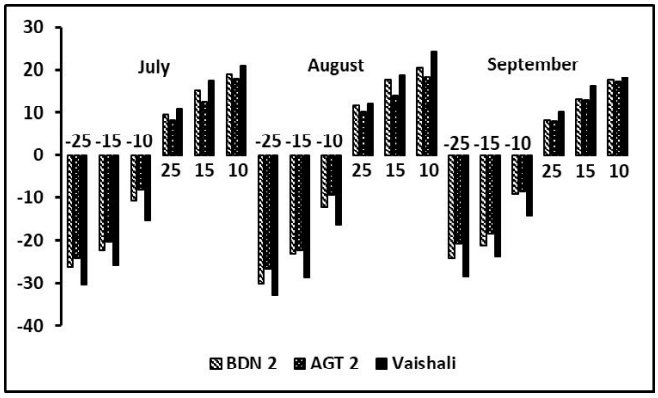


**Fig. 3:** Per cent change in seed yield (%) due to intra seasonal variation of rainfall in different varieties

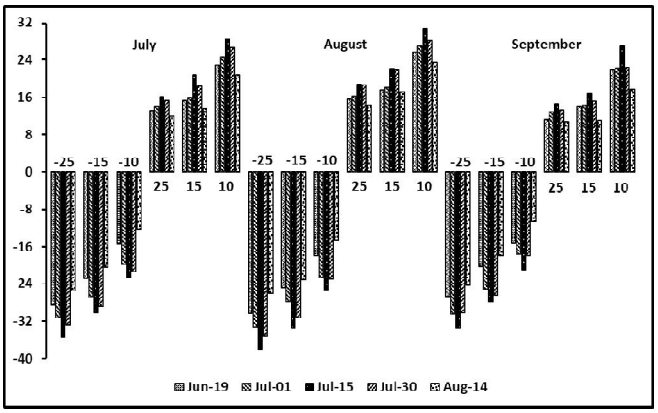


**Fig. 4:** Per cent change in seed yield (%) due to intra seasonal variation of rainfall in different dates of sowing

different cultivars was slightly less than that observed with maximum temperature (Table 3). The increase in minimum temperature up to $3^0$C had highest (-10.6%) yield reduction in cv. BDN 2 followed by -10.2 per cent in Vaishali and -9.7 per cent in AGT 2. Cultivar AGT 2 having highest yield (Table 1) was least influenced by change in maximum and minimum temperatures in comparison to other two cultivars.

***Effect of temperature under different sowing environment***

The effect of change in maximum and minimum temperatures during crop growing period on seed sown on different dates (June 19, July 1, July 15, July 30 and August 14) revealed that the seed yield decreased with increase in temperature and vice versa under all the five dates of sowing (Table 4). It is seen that the extent of variation in seed yield varied with the dates of sowing. The maximum effect (+10.5 to -11.0%) was observed in early sown ($D_1$ – June 19) and lowest variation (+8.6 to -9.0%) was in late sown ($D_5$- August 14) pigeon pea due to change in maximum temperature from -3 to $+3^0$C respectively. The late sown crop produced less seed yield and was least affected by the change in temperature. The increase in maximum temperature by $3^0$C caused highest yield reduction (-11.0%) on crop sown on June 19, followed by July 1 sown crop (-10.7%). Higher seed yield reduction may be due to increased temperature which caused increase in rate of respiration resulted higher loss of photosynthates. About 10.2, 9.6 and 9 percent yield reduction was observed under July15, 30 and August 14 sown pigeon pea respectively (Table 4).

The effect of change in minimum temperature on seed yield of pigeon pea under different dates of sowing was lower than that observed with maximum temperature. The early sown pigeon pea (June 19) was affected more with change in minimum temperature in comparison to other sowing dates (Table 4).

***Effect of intra-seasonal change in temperature***

The effect of intra-seasonal change in temperatures during crop growing period (June to January) on seed sown revealed that the seed yield decreased with increase in temperature and vice versa (Fig. 2).The maximum effect (+11.6 to -10.5%) was observed during October month and lowest (+2.9 to -5.2%) during June month. The increase in temperature by $3^0$C caused highest reduction (-11.4%) during September month. Higher decrease in seed yield during September and October may be due to the fact that higher temperature during developmental stage affected the pollination which is one of the sensitive phenological stage.

***Effect of rainfall variations***

The effect of increase and/or decrease in rainfall by±10, ±15 and ±25 per cent in the months of July, August and September on seed yield of three varieties of pigeon pea are presented in Fig. 3. It is seen that the increase in rainfall caused increase in seed yield in all the cultivars, the magnitude varied with the cultivars, as well as the period and the extent of increase rainfall. The variation was highest (-32.8% to 24.3%) in Cv. Vaishali ($V_3$) during August month followed by BDN 2 (-30.2% to 20.5%) and AGT 2 (-26.7% to 18.5%). Rainfall during August month affected the seed yield most followed by July and September in all the varieties.Dubey *et al*., (2011) reported that the decline in rainfall decreased the seed yield of pigeon pea. Variety AGT 2 was least affected due to rainfall as well as temperature. Among the dates of sowing, the variation in seed yield due to change in rainfall was maximum (-37.8% to 30.7%) in July 15sown and least (-26.0% to 23.5%) sown crop in August 14 (Fig. 4).

## CONCLUSION

The CROPGRO- pigeon pea model of DSSAT family, calibrated and validated for three cultivars of pigeon pea, simulated the seed yield under different environments satisfactorily with error percent less than 10. Hence this model can be used for studying the effect of different environments and management practices on pigeon pea crop in middle Gujarat. The increase and decrease in maximum and minimum temperatures had negative/positive impact of seed yield of pigeon pea, the extent of which varied with cultivars, time of sowing and the period/month of temperature change. High yielding variety AGT 2 was least affected by change in temperature and rainfall while Cv. Vaishali was most affected due to temperatures and rainfall. Rainfall during August was found to have favourable effect on the seed yield of pigeon pea. Early sown pigeon pea were most affected by change in temperature while July sown crops were most affected by rainfall.

## ACKNOWLEDGEMENT

This work has been carried out under Emeritus Scientist Scheme of ICAR, the financial support provided is duly acknowledged. Authors are thankful to Anand Agricultural University, Anand for providing the facilities to carry out the work.

## REFERENCES

Anonymous (2017). Department of Economics and Statistics, Govt. of India.

Birthal, P. S., Tajuddin K. M., Negi, D. S. and Agarwal, S. (2014). Impact of Climate Change on Yields of Major Food Crops in India: Implications for Food Security. *Agric. Econ. Res. Rev.,* 27 (2): 145-155.

Dubey, S. K., Sah, U. and Singh, S. K. (2011). Impact of climate change on pulse productivity and adaptation strategies as practiced by the pulse growers of Bundelkhand region of Uttar Pradesh. *J. Food Legumes*., 24(3): 230-234.

Hoogenboom, G., Jones, J. W., Wilkens, P. W., Porter, C. H., Batchelor, W. D., Hunt, L. A., Boote, K. J., Singh, U., Uryasev, O., Bowen, W. T., Gijsman, A. J., Du Toit, A., White, J. W. E. and Tsuji, G. Y. Decision support system for agro technology transfer: version 4.0. Honolulu: University of Hawaii, 2004.

Kesava Rao, A.V.R., Wani, S.P., Komuravelly, S., Singh, P., Bairagi, S.D. and Ramadevi, O. (2013). Assessing impacts of projected climate on pigeon pea crop at Gulbarga. *J. Agrometeorol.,* 15 (Special Issue-II): 32-37.

Kumar,S. C. V., Mula1, M. G., Singh, I. P., Mula, R. P., Rachit, K. S., Ganga, R. N. V. P. R. and Rajeev,K. V. (2014). Pigeonpea Perspective in India. Paper presented during the '1st Philippine Pigeonpea Congress'. Mariano Marcos State University, Batac, Ilocos Norte, Philippines. December 16-18

Lohot, V. D., Ghosh, Ghosal, S. Thamilarasi, K., Gunjan. and Sharma, K. K. (2018). Effect of lac culture on seed quality traits of Pigeon pea [*Cajanus cajan* (L.) Millsp.]. *J. Entomol. Zool. Studies*, 6(2): 2296-2301.

Patil, D. D., Pandey, Vyas., Acharya, R. R. and Baria, L. N. (2018). Effect of intra-seasonal variation in temperature on tuber yield of potato in middle Gujarat using SUBSTOR model. *J. Agrometeorol.*, 20 (1): 22-27.

Patil, D. D. and Patel, H. R. (2017). Calibration and validation of COPGRO (DSSAT 4.6) model for chickpea under middle Gujarat agroclimatic region. *Int. J. Agril. Sci.,* 9 (27): 4342- 4344.

Sandhu, S. S., Prabhjyot Kaur, Padmakar, T., Patel, S. R., Rajinder, P., Solanki, N. S., Singh R. K,, Dubey, A. P. and Rao, V. U. M. (2016). Effect of intra-seasonal temperature on wheat at different locations of India: A study using CERES-Wheat model. *J. Agrometeorol*., 18 (2): 222-233.

Yadav, M. K., Singh, R.S., Singh, K. K., Mall, R. K., Patel, C., Yadav, S. K. and Singh, M. K. (2016). Assessment of climate change impact on pulse, oilseed and vegetable crops at Varanasi, India. *J Agrometeorol.,* 18(1): 13-21.

*Received : August 2018 ; Accepted : October 2018*