RESEARCH ARTICLE Legume Research- An International Journal, Volume 46 Issue 7: 843-848 (July 2023)

# Physiology and Yield of Chickpea (*Cicer arietinum* L.) Genotypes in Response to Different Sowing Dates in Semi Arid Regions of North India

Ajeev Kumar[1], Neeraj Kumar[1], Sarita Devi[1], Anil Kumar Dhaka[2], Satish Khokhar[2]

10.18805/LR-5108


## ABSTRACT

**Background:** Climate change causes variation in global temperature in last two decades which causes detrimental effects on agricultural crops being grown in arid and semi-arid regions. Chickpea crop sensitive to variation in temperature as the late-sown crop is exposed to high temperatures (>35°C) at its reproductive stage in the months of February and March and early sown crops is exposed to low temperature (<5°C) at its vegetative stage in December and January so optimum sowing time plays a vital role for overall growth and development of the plants.

**Methods:** The experiment comprising of three sowing dates that is 15th October (early sown condition in Haryana), 15th November (Normal sown condition in Haryana) and 15th December (late sown condition in Haryana) with ten chickpea (*Cicer arietinum* L.) genotypes namely ICCV 88503, ICCV 92944, HC-1, HC-3, HC-5, H12-64, H13-01, H13-02, H14-01 and H14-04 in randomized block design during *Rabi* season of 2017-18 and 2018-19 at Pulses Section, Chaudhary Charan Singh Haryana Agricultural University, Hisar.

**Result:** Statistically no significant differences in seed yield was recorded between 15th October and 15th November sowing, however, further delay in sowing to 15th December showed significant reduction in seed yield while maximum values for recorded physiological parameters in chickpea genotypes were found in 15th November sowing and minimum in 15th December sowing. Among genotypes maximum physiological parameters and seed yield were observed in H12-64 and H13-01 while minimum were found in H14-04.


**Key words:** Chickpea, Chlorophyll, Genotypes, Physiology, Sowing dates.

## INTRODUCTION

Chickpea is the second most important legume crop after dry beans in the world with 14.5 million hectare area under cultivation and 14.7 million tonnes are produced annually with average seed yield of 1014 kg ha$^{-1}$ (FAOSTAT, 2020) whereas in India with 10.76 million hectare area under cultivation and 11.1 million tonnes produced with average seed yield of 1031 kg ha$^{-1}$ (Anonymous, 2019-20). In Haryana, it is grown over an area of 107,000 hectare with total production of 91,000 tonnes and productivity of 850 kg ha$^{-1}$ (Anonymous, 2019-20).

In India, Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Andhra Pradesh, Karnataka, Chhattisgarh, Bihar and Jharkhand are major chickpea cultivating and producing states contributing more than 95% to the total chickpea area and production. Madhya Pradesh is the single largest producer in the country accounting for over 41% of total production while Maharashtra, Rajasthan, Karnataka, Uttar Pradesh, Andhra Pradesh and Haryana contribute about 16, 13, 8, 6, 6 and 1.5% while area contribute about 34, 19, 17, 13, 6, 5 and 1.2% respectively. Sowing time is different for different varieties in a specific area and the optimum sowing time and highly productive cultivars can accelerate the growth, development and yield of the specific crop because sowing time can influence different climatic parameters, such as temperature, moisture, sunlight, *etc*. affecting plant growth (Bazvand *et al*., 2015). The high temperature at late sown condition may adversely affect the productivity of crops as both duration and grain filling stages are sensitive to alteration in temperature and also impact on morphological, physiological and biochemical behaviour of the crop (Moradshahi *et al*., 2004). High temperature can affect many physiological processes into plants like photosynthesis, respiration, membrane stability and water status that results into increased concentrations of a variety of heat shock proteins (HSPs) and production of reactive oxygen species (Wahid and Close, 2007). However, during

[1]Department of Botany and Plant Physiology, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125 004, Haryana, India.

[2]Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125 004, Haryana, India.

**Corresponding Author:** Ajeev Kumar, Department of Botany and Plant Physiology, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125 004, Haryana, India.
Email: ajeevk490@gmail.com

**How to cite this article:** Kumar, A., Kumar, N., Devi, S., Dhaka, A.K. and Khokhar, S. (2023). Physiology and Yield of Chickpea (*Cicer arietinum* L.) Genotypes in Response to Different Sowing Dates in Semi Arid Regions of North India. Legume Research. 46(7): 843-848. doi: 10.18805/LR-5108.

**Submitted:** 02-02-2023 **Accepted:** 16-05-2023 **Online:** 31-05-2023

early sown conditions, temperature below 10°C is known to alter a variety of physiological processes ranging from plant water status, photosynthesis to reactive oxygen species (ROS) and solute accumulation, excessive floral abortion and has adverse effect on chickpea yield and results in losses from 15-20% (Bakht *et al*., 2006; Chaturvedi *et al*., 2009). The present investigations was thus taken up to study the physiological and yield traits under different dates of sowing to screen out promising chickpea genotypes.

## MATERIALS AND METHODS

Hisar is located in North-West India at 215.2 meters above mean sea level with latitude of 29°10′ North and longitude of 75°46′ East. The minimum temperature in this area reaches upto 0.5°C in December and January and the maximum temperature in the area reaches upto 48°C during May or June. The mean weekly maximum temperature ranged between 16.9 to 39.3°C and minimum between 2.6 to 20.6°C, while, their corresponding values in 2018-19 were 17.1 to 40.7°C and 1.9 to 20.6°C respectively (Fig 1 and 2). Water potential (WP) of third leaves was measured with the help of Pressure Chamber. Osmotic potential (OP) was determined using psychrometric technique (Model 5100- B Vapor Pressure Osmometer). Calculation of (Relative water content) RWC (%) of leaves according to the formula given by Weatherley, (1950):

$$RWC\ (\%) = \frac{\text{Fresh weight - Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

Membrane injury index (RSI) was measured as percent proportion of ion leakage in to the external aqueous medium to the total ion concentration of the stressed tissue as measured by the EC of the external medium (Sullivan and Ross, 1979).

$$RSI\ (\%) = \frac{EC_1}{EC_2} \times 100$$

Chlorophyll content was estimated according to the method of Hiscox and Israelstam (1979) using dimethyl sulfoxide (DMSO). Canopy temperature depression (CTD) measurements were made by using a handy Infra-red Thermometer (Model AG-42, Tele-temp Corp. CA). The number of branches emerging directly from the main stem counted at harvesting and average was recorded. The total number of pods obtained from five randomly selected plants was recorded and expressed as number of pods plant$^{-1}$. 100 seed were counted randomly from each genotypes and the test weight (g) was recorded. The completely matured plants were uprooted carefully along with roots and were dried completely. The weight of dried plant along with pods was recorded as biological yield (kg/ha). Harvest index is represented in terms of percentage.

$$HI = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

Data were subjected to pooled analysis of both year (2017-18 and 2018-19) and analysis of (ANOVA) using Online Statistical Analysis Package (OPSTAT) Computer Section, CCS Haryana Agricultural University, Hisar.

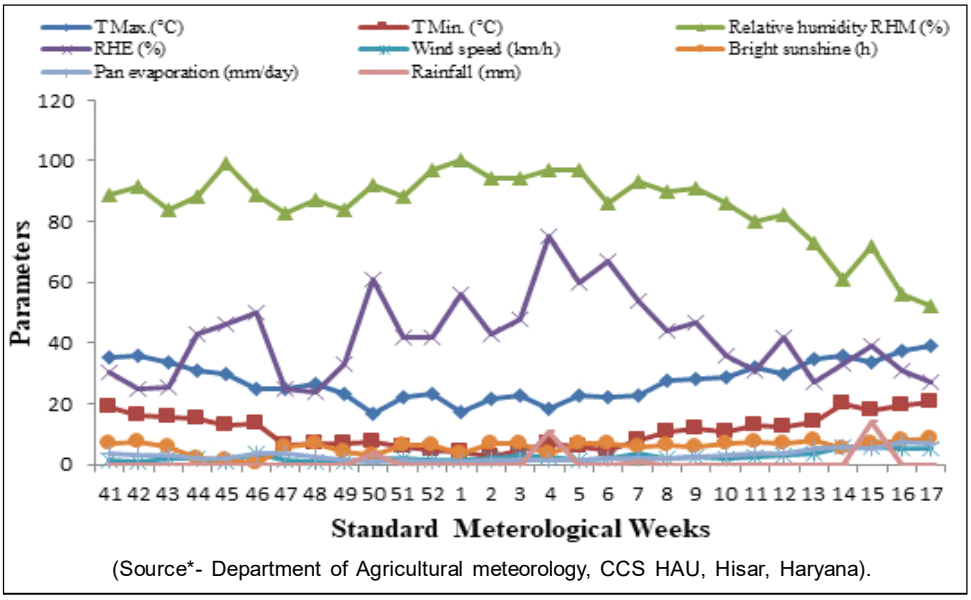
## RESULTS AND DISCUSSION

### Physiological parameters

The different parameters of plant water status *i.e* leaf water potential ($y_w$), leaf osmotic potential ($y_s$) and leaf relative water (RWC) content were affected by different dates of sowing. The water status of plant decides the rate of several physiological processes related to growth and development. In the present investigation, among three dates of sowings, lowest leaf water potential (-0.35 Mpa), osmotic potential (-0.87 Mpa) and relative water content (61.5%) were recorded in 15$^{th}$ December and highest (-0.30 Mpa, -0.71 Mpa, 88.5%, respectively) in November 15$^{th}$ sowing (Table 1). This might be due to the reason that the high temperature (Max. temp. 28.9°C, Min. temp. 11.8°C) higher bright sunshine hours (7.2 h), more evaporation rate (4.0 mm/day) in 15 December sowing condition at 50% flowering stage that resulted into more transpiration rate while in 15$^{th}$ November sowing at 50% flowering stage the temperature (Max. temp. 22.2°C, Min. temp. 9.0°C), bright sunshine hours (5.6 h), evaporation rate (1.2 mm/day) were quite low as compared to 15$^{th}$ December sowing that causes less transpiration rate that resulted into higher water potential, osmotic potential and RWC at 15$^{th}$ November sowing. Similar results due to variation in temperature has also been reported earlier in the literature by (Singh *et al*., 2004; in chickpea, Sudhir *et al*., 2013 and Ram *et al*., 2015 in mustard). The data in Table 1 showed that highest values of leaf water potential, osmotic potential and relative water content in genotypes were recorded in genotype H12-64 and H13-01 whereas, minimum were in H14-04. These variation in genotypes is due their tolerance behaviour at low and high temperature condition and similar results also has been reported earlier in the literature by Singh *et al*. (2004); Sudhir *et al*. (2013); Ram *et al*. (2015).

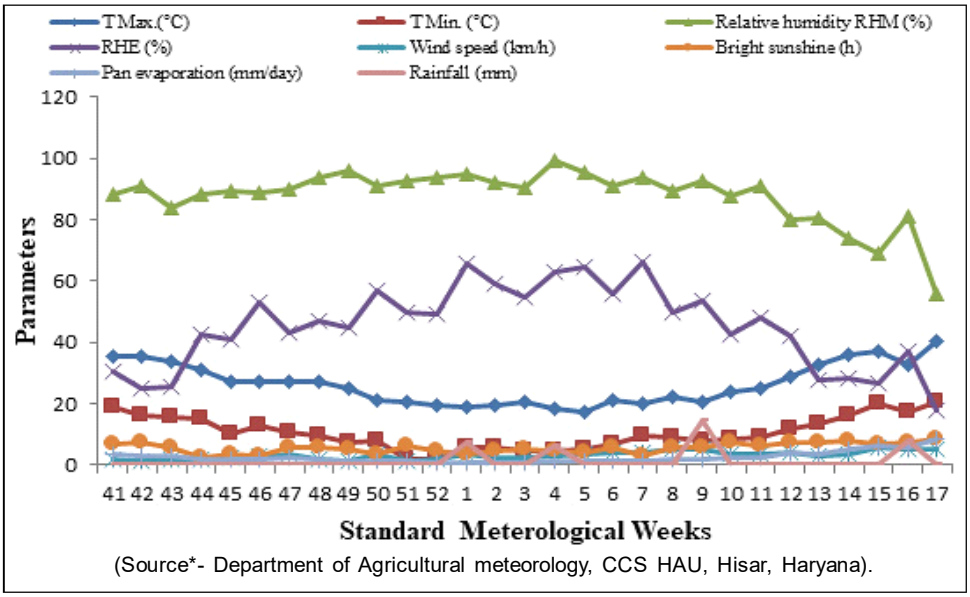
The measurement of membrane injury is considered as a standard method for screening the material against stress tolerance and hence to study physiological response of chickpea at different sowing dates. The data in Table 1 showed that highest (11.26%) relative stress injury (RSI) was recorded in genotype H14-04 whereas, minimum relative stress injury (RSI) was in H13-01 (9.33%). These variation in genotypes is due their tolerance behaviour at low and high temperature condition. Similar results has also been reported earlier in the literature by Basu *et al*. (2011); Kumar *et al*. (2012) in chickpea. In the present investigation, among three dates of sowings, lowest (9.86%) relative stress injury (RSI) was recorded in crop sown on 15$^{th}$ November and highest (11.03%) in December 15$^{th}$ sowing. This might be due to the reason that the high temperature (Max. temp. 28.9°C, Min. temp. 11.8°C) in 15$^{th}$ December sowing condition at 50% flowering stage that resulted into more leakage of ions while in 15$^{th}$ November sowing at 50% flowering stage the temperature (Max. temp. 22.2°C, Min.

temp. 9.0°C) was optimum as compared to 15th December sowing that causes less leakage of ions so the increment of 6.7°C temperature in 15th December sowing, resulted into more relative stress injury. Similar results has also been reported earlier in the literature by (Basu *et al*., 2011; Kumar *et al*., 2012 in chickpea; Mohammed and Tarpley, 2010 in rice; Kumar *et al*., 2011 in mungbean; Ram *et al*., 2012 in Indian mustard). Leaf temperatures are depressed below air temperature when the temperature above the optimal condition with water evaporates from their surface was noticed as canopy temperature depression (CTD). Among three dates of sowings, lowest (-2.20°C) canopy temperature depression was recorded in crop sown on 15th December and highest (-0.28°C) in November 15th sowing. This might be due to variations in temperature (max 22.2 to 28.9°C and min 9.0 to 11.8°C), sunshine hours (5.6 to 7.2 hrs) at 50% flowering stages in 15th November and 15th December sowing dates respectively. These results are in agreement with the results obtained by Basu *et al*. (2011); Kumar *et al*. (2012) in chickpea; Basu *et al*. (2014) in wheat. The data in Table 1 showed that highest (-0.50°C) canopy temperature depression in genotypes was recorded in genotype H13-01 whereas minimum canopy temperature depression was in H14-04 (-1.70°C). Similar results also documented earlier by Basu *et al*. (2011); Kumar *et al*. (2012) in chickpea. Chlorophyll content play an important role in photosynthetic activity. Due to higher chlorophyll content, light absorption rate and photosynthetic rate increases. The green plant




(Source*- Department of Agricultural meteorology, CCS HAU, Hisar, Haryana).

**Fig 1:** Mean weekly values of weather parameters during cropping season of 2017-18.




(Source*- Department of Agricultural meteorology, CCS HAU, Hisar, Haryana).

**Fig 2:** Mean weekly values of weather parameters during cropping season of 2018-19.

pigments are thermo sensitive and their degradation occurs when subjected to higher temperature. In present investigation, decrease in chlorophyll was observed with delayed sowings beyond 15th November (Table 1). Among three dates of sowings, lowest chlorophyll (3.516 mg $g^{-1}$ DW) was recorded in crop sown on 15th December and highest (5.402 mg $g^{-1}$ DW) in November 15th sowing at 50% flowering stage. This might be due to high temperature and low leaf area index at 50% flowering stage in 15th December sowing as compared to 15th November sowing. These results also in the same line as observed by Almeselmani *et al*. (2006); (2009) in wheat; mungbean; Kumar *et al*. (2011) in mungbean; Kaushal *et al*. (2011) in chickpea. Among genotypes, highest chlorophyll (5.027 mg $g^{-1}$DW) was recorded in genotype H13-01 whereas minimum (4.160 mg $g^{-1}$ DW) in H14-04. These variation in genotypes is due to differences in water status. Similar results also observed by Kumar *et al*. (2011) in mungbean; Kaushal *et al*. (2011) in chickpea.

**Yield and its attributes**

Yield is a complex character which involves the interaction of several intrinsic and external factors. It largely depends upon the production and mobilization of carbohydrates, uptake of water and nutrients from the soil, in addition to

**Table 1:** Effect of sowing dates on physiological parameters in chickpea (*Cicer aritienum* L.) genotypes.

| Sowing dates | WP (-Mpa) | OP (-Mpa) | RWC (%) | RSI (%) | CTD (°C) | Chlorophyll (mg $g^{-1}$DW) |
|---|---|---|---|---|---|---|
| 15th Oct | 0.32 | 0.83 | 83.53 | 10.54 | 0.69 | 5.067 |
| 15th Nov | 0.30 | 0.71 | 88.54 | 9.86 | 0.28 | 5.402 |
| 15th Dec | 0.35 | 0.87 | 61.51 | 11.03 | 2.20 | 3.516 |
| CD at 5% | 0.01 | 0.02 | 5.41 | 0.08 | 0.02 | 0.112 |
| **Genotypes** | | | | | | |
| H12-64 | 0.26 | 0.73 | 81.06 | 9.43 | 0.50 | 4.896 |
| H13-01 | 0.26 | 0.73 | 82.30 | 9.33 | 0.50 | 5.027 |
| H13-02 | 0.28 | 0.77 | 79.00 | 10.07 | 1.20 | 4.824 |
| H14-01 | 0.29 | 0.76 | 81.43 | 10.75 | 1.00 | 4.750 |
| H14-04 | 0.44 | 0.99 | 67.12 | 11.26 | 1.70 | 4.160 |
| HC 1 | 0.33 | 0.79 | 77.81 | 10.77 | 1.10 | 4.523 |
| HC 3 | 0.34 | 0.81 | 78.31 | 10.89 | 0.90 | 4.729 |
| HC 5 | 0.35 | 0.83 | 77.23 | 10.87 | 1.10 | 4.616 |
| ICCV88503 | 0.32 | 0.80 | 76.78 | 10.47 | 1.40 | 4.581 |
| ICCV92944 | 0.35 | 0.82 | 77.12 | 10.86 | 1.00 | 4.509 |
| CD at 5% | 0.01 | 0.03 | 7.51 | 0.16 | 0.01 | 0.173 |

WP- Water potential; OP- Osmotic potential; RWC- Relative water content; RSI- Relative stress injury; CTD- Canopy temperature depression.

**Table 2:** Effect of sowing dates on yield and its attributes in chickpea (*Cicer aritienum* L.) genotypes.

| Sowing dates | No. of Branches/plant | No. of pods/plant | Test weight (gm) | Biological yield (Kg/ha) | Seed yield (Kg/ha) | Harvest index (%) |
|---|---|---|---|---|---|---|
| 15th Oct | 6.2 | 79.0 | 16.12 | 6923 | 2114 | 30.5 |
| 15th Nov | 5.4 | 76.9 | 15.53 | 6839 | 2090 | 30.5 |
| 15th Dec | 3.9 | 43.5 | 13.47 | 6333 | 1890 | 29.5 |
| CD at 5% | 0.1 | 0.8 | 0.11 | 67 | 36 | 0.4 |
| **Genotypes** | | | | | | |
| H12-64 | 5.2 | 73.1 | 16.21 | 7197 | 2255 | 31.3 |
| H13-01 | 5.2 | 77.7 | 16.45 | 7358 | 2326 | 31.6 |
| H13-02 | 4.9 | 72.9 | 15.82 | 6992 | 2191 | 31.3 |
| H14-01 | 4.8 | 69.1 | 15.38 | 6892 | 2063 | 29.9 |
| H14-04 | 4.4 | 43.0 | 13.10 | 5625 | 1594 | 27.1 |
| HC 1 | 4.6 | 54.6 | 14.39 | 6408 | 1926 | 30.1 |
| HC 3 | 4.6 | 66.3 | 15.26 | 6926 | 2046 | 29.5 |
| HC 5 | 4.6 | 58.3 | 14.59 | 6915 | 2021 | 29.2 |
| ICCV88503 | 5.1 | 62.0 | 14.31 | 6618 | 1988 | 30.0 |
| ICCV92944 | 4.8 | 54.3 | 14.88 | 6052 | 1903 | 31.4 |
| CD at 5% | 0.1 | 1.4 | 0.30 | 122 | 66 | 0.6 |

several environmental factors to which plant is exposed during the growing period. The minimum seed yield (1889 kg/ha) and its attributes were observed in plants sown on 15th December and maximum seed yield (2113 kg/ha) and its attributes were observed on 15th October sowing and 15th November (2090 kg/ha) sown crop (Table 2). This might be due to comparatively favorable climatic conditions such as plant water status, temperature, photoperiod, sunshine hours, photosynthetic rate and chlorophyll content in 15th October and 15th November sowing than 15th December sowing. Lower seed yield during late sowing (15th December) might be due to shorter grain filling period as a result of high temperature at grain filling stages and unfavourable conditions. Among genotypes, highest yield attributes and yield (2326 kg/ha) was recorded in genotype H13-01 and H12-64 (2255 kg/ha) whereas minimum (1594 kg/ha) in H14-04. This variation among genotypes might be due to differences in physiological traits that might be responsible for production potential. Similar result also reported earlier in the literature (Krishnamurthy *et al*., 2011; Mrudula *et al*., 2013; Pawar, 2015; Husnain *et al*., 2015; Sekhar *et al*., 2015; Patil *et al*., 2017; Ali *et al*., 2018; Bhasker *et al*., 2018; Meena *et al*., 2018 in clusterbean and Chaudhary *et al*., 2020 in Indian bean) due to different sowing dates.

## CONCLUSION

Based upon various physiological traits and yield attributes, chickpea genotypes H12-64 and H13-01 were found to be promising in all the sowing dates and can be used in further breeding programme of chickpea for early (cold tolerance) and late (heat tolerance) sown conditions. It is concluded that these genotypes in future may prove better for late sown conditions (heat tolerance) and can be used in hybridization programme of chickpea. Maximum physiological parameters and seed yield were recorded between 15th October and 15th November sowing, however, further delay in sowing to 15th December, significant reduction in physiological parameters as well as seed yield were recorded.

**Conflict of interest:** None.

## REFERENCES


Ali, M.Y., Biswas, P.K., Shahriar, S.A., Nasif, S.O. and Raihan, R.R. (2018). Yield and quality response of chickpea to different sowing dates. Asian Journal of Research in Crop Science. 1(4): 1-8.

Almeselmani, M., Deshmukh, P.S., Sairam, R.K., Kushwaha, S.R. and Singh, T.P. (2006). Protective role of antioxidant enzymes under high temperature stress. Plant Science, 171: 382-388.

Anonymous, (2019-20). Progress Report 2019-20. All India Coordinated Chickpea Improvement Project.

Bakht, J., Asghari, B. and Dominy, P. (2006). The role of abscisic acid and low temperature in chickpea (*Cicer arietinum*) cold tolerance and effects on plasma membrane structure and function. Journal of Experimental Botany. 57: 3707-3715.

Basu, P.S., Ali, M. and Chaturvedi, S.K. (2011). Terminal Heat Stress Adversely Affects Chickpea Productivity in Northern India-Strategies to Improve Thermotolerance in the Crop under Climate Change. In: Workshop Proceedings: Impact of Climate Change on Agriculture, pp. 189-194.

Bazvand, F., Pezeshkpour, P. and Mirzaie, A. (2015). Chickpea (*Cicer arietinum* L.) yield and yield components as affected by sowing date and genotype under rainfed conditions. Bulletin of Envvironment and Pharmacological Life Sciences. 4(11): 59-65.

Bhasker, P., Nandwal, A.S., Kumar, N., Chand, G., Yadav, S.P., Devi, S. and Singh, S. (2018). High temperature significance of anthocyanins accumulation stress responses in chickpea (*Cicer arietinum* L.). International Journal of Agriculture Innovations and Research. 6(6): 2319-1473.

Chaturvedi, S.K., Mishra, D.K., Vyas, P. and Mishra, N. (2009). Breeding for cold tolerance in chickpea. Trends in Biosciences. 2: 1-6.

Chaudhary, R., Kushwah, S.S., Sharma, R.K. and Kachouli (2020). Effect of sowing dates on growth, flowering and yield of Indian bean varieties under agroclimatic conditions of Malwa Plateau in Madhya Pradesh. Legume Research. 43: 539-545.

FAOSTAT, (2020). Food and Agriculture Organization of the United Nations (FAO) Statistical Databases. www.fao.org.

Hiscox, J.D. and Isrealstam, G.F. (1979). A method for the extraction of chlorophyll from leaf tissue without maceration. Canadian Journal of Botany. 57: 1332-1334.

Husnain, M.S., Mahabub, S.T., Mazed, H.E.M.K., Habib, Z.F.B. and Pulok, A.I. (2015). Effect of sowing time on growth, yield and seed quality of chickpea (BARI chhola-6). International Journal of Multidisciplinary Research and Development. 7: 136-141.

Kaushal, N., Gupta, K., Bhandhari, K., Kumar, S., Thakur, P. and Nayyar, H. (2011). Proline induces heat tolerance in chickpea (*Cicer arietinum* L.) plants by protecting vital enzymes of carbon and antioxidative metabolism. Physiology and Molecular Biology of Plants. 17: 203-213.

Krishanamurthy, L., Gaur, P.M., Basu, P.S., Chaturvedi, S.K., Tripathi, S., Vadez, V., Rathore, A., Varshaney, R.K. and Gowda, C.L.L. (2011). Large genetic variation for heat tolerance in the reference collection of chickpea (*Cicer arietinum* L.) germplasm. Plant Genetic Resources. 9: 59-61.

Kumar, N., Nandwal, A.S., Yadav, R., Bhasker, P., Kumar, S., Devi, S., Singh, S. and Lather, V.S. (2012). Assessment of chickpea genotypes for high temperature tolerance. Indian Journal of Plant Physiology. 17(3 and 4): 224-232.

Kumar, S., Kaur, R., Kaur, N., Bhandhari, K., Kaushal, N., Gupta, K., Bains, T.S. and Nayyar, H. (2011). Heat-stress induced inhibition in growth and chlorosis in mungbean (*Phaseolus aureus Roxburghi*) is partly mitigated by ascorbic acid application and is related to reduction in oxidative stress. Acta Physiologia Plantarum. 33: 2091-2101.

Meena, H., Meena, R.S., Lal, R., Yadav, G.S., Mitran, T., Layek, J., Patil, S.B., Kumar, S. and Verma, T. (2018). Response of sowing dates and bioregulators on yield of clusterbean under current climate in alley cropping system in eastern U.P., India. Legume Research. 41(4): 563-571.

Mohammed, A.R. and Tarpley, L. (2010). Effects of high night temperature and spikelet position on yield-related morphology in cowpea. Crop Science. 39: 1762-1768.

Moradshahi, A., Eskandari, B.S. and Kholdebarin, B. (2004). Some physiological responses of canola (*Brassica napus* L.). Iranian Journal of Science and Technology. 28: 43-50.

Mrudula G, Rani Y.A., Madhan, M., Mohan and Reddy, M.V.S. (2013). Influence of plant physiological chararacters on yield of chick pea (*Cicer arietinum* L.) genotypes. Progressive Research. 8(1): 133-134.

Patil, D.D., Nayak, M.K. and Patel, H.R. (2017). Effect of dates of sowing and irrigation levels on yield and yield attributing characters of chickpea. International Journal of Agriculture Sciences. 9(20): 4220-4221.

Pawar Nandu, B. (2015). Effect of extended sowing dates on growth and yield of chickpea. International Journal of Recent Scientific Research. 6(10): 6884-6887.

Ram, B., Singh, B.K., Singh, M., Singh, V.V. and Chauhan, J.S. (2012). Physiological and molecular characterization of Indian mustard (*Brassica juncea* L.) genotypes for high temperature tolerance. Crop Improvement (Special issue) ICSA: 5-6.

Ram, B., Singh, V.V., Singh, B.K., Priyamedha, Kumar, A. and Singh, D. (2015). Comparative tolerance and sensitive response of indian mustard [*Brassica juncea* (L.) czern and coss] genotypes to high temperature stress. SABRAO Journal of Breeding and Genetics. 47(3): 315-325.

Sekhar, D., Kumar, P. and Rao, K.T. (2015). Performance of chickpea varieties under different dates of sowing in high altitude zone of Andhra Pradesh, India. International Journal of Current Microbiology and Applied Sciences. 4(8): 329-332.

Singh, T.P., Deshmukh, P.S. and Kushwaha, S.R. (2004). Physiological studies on temperature tolerance in chickpea (*Cicer arietinum* L.) genotypes. Indian Journal of Plant Physiology. 9(3): 294-301.

Sudhir, K., Sairam, R.K. and Prabhu, K.V. (2013). Physiological traits for high temperature stress tolerance in *Brassica juncea*. Indian Journal of Plant Physiology. 18: 89-93.

Sullivan, C.Y. and Ross, W.M. (1979). Stress Physiology and Crop Plants, John Wiley and Sons, New York. 263-281.

Wahid, A. and Close, T.J. (2007). Expression of dehydrins under heat stress and their relationship with water relations of sugarcane leaves. Biology of Plants. 51: 104-109.

Weatherley, P.E. (1950). Studies on the water relations of the cotton plant, The field measurement of water deficit in leaves. New Phytologist. 40: 81-97