Indian J. Genet. Plant Breed., (2023); 83(2): 270-272
https://doi.org/10.31742/ISGPB.83.2.14
ISSN: 0975-6906
www.isgpb.org

SHORT RESEARCH ARTICLE

Capturing genetic variability in chickpea (*Cicer arietinum* L.) germplasm, released varieties, and advanced breeding lines under heat stress environment in North Indian climatic condition

Uday C. Jha*, Yogesh Kumar and Pradip K. Katiyar

Abstract

Temperatures beyond optimal level are detrimental to growth and production in chickpeas. Aiming at capturing genetic variability and identifying potential heat-tolerant chickpea genotype, a panel of 110 chickpea lines were evaluated in field under normal sown (non-stress) and late sown (heat-stress) environments for various phenological, yield and yield-related traits over two consecutive years under field conditions. Significant genetic variability for the phenological and yield related) was recorded under both non-stress and heat-stress conditions for both years. Seed yield/plant had strong positive correlations with number of pods/plant and harvest index under heat stress, indicating selection of plants with high pods/plant and seed yield/plant could help develop a heat-tolerant chickpea line. Based on the yield and yield-related traits, JG74, JAKI9218, Pusa 547, GNG1958, RVG202, RSG11, RSG931, RSG10, GG2, and Pusa240 genotypes were classified as promising lines under heat stress environment. The identified diverse heat-tolerant genotypes may be used as a potential source in chickpea breeding programme for enhancing heat tolerance and useful genetic variability.

Keywords: Chickpea, heat stress, food security, genetic variability, climate change

Elevated environmental temperature is becoming a serious impediment to crop growth and yield, including chickpeas globally, risking global food security (Hasanuzzaman et al. 2013). Environment temperature beyond normal ambient temperature is detrimental to all the crop growth stages, including vegetative and reproductive stages, resulting in significant yield loss in chickpeas worldwide (Bhandari et al. 2020; Chaudhary et al. 2020; Rani et al. 2020). Chickpea, being a cool season legume crop, frequently encounters episodic heat stress events during reproductive stages, especially pod development and grain filling stages, leading to significant yield losses (Devasirvatham et al. 2012, 2013; Rani et al. 2020; Devi et al. 2022). In recent years, evidence of an increase in environmental temperature during pod filling and maturity stages render significant yield limitation in chickpea (Krishnamurthy et al. 2011). Usually, the sudden rise in temperature beyond normal causes hastening of crop phenology, including days to flowering, days to pod filling and maturity, thus resulting in poor biomass development and ultimately low filled pods and plant yield (Bhandari *et al.* 2020). Developing terminal heat stress resilient chickpea genotypes is urgently needed to sustain the yield under hot environments. The current study was, therefore, aimed at the assessment of the existing genetic variability for heat tolerance and to identify potential heat tolerant donors in a set of diverse chickpea genotypes by growing them under normal (non-stress) and late sown conditions (heat stress) in field conditions for two years.

One hundred and ten chickpea genotypes, comprising of released varieties, landraces and advanced breeding lines were evaluated in field under normal (non-stress) and late sown (heat stress) for over two consecutive years during 2017-18 and 2018-19 (Supplementary Table S1). The materials were grown in alpha lattice design with two replications

ICAR-Indian Institute of Pulses Research (IIPR), Kanpur 208 024, Uttar Pradesh, India

***Corresponding Author:** Uday C Jha, ICAR-Indian Institute of Pulses Research, Kanpur 208 024, Uttar Pradesh, India, E-Mail: uday_gene@yahoo.co.in

How to cite this article: Jha U.C., Kumar Y. and Katiyar P.K. 2023. Capturing genetic variability in chickpea (*Cicer arietinum* L.) germplasm, released varieties, and advanced breeding lines under heat stress environment in North Indian climatic condition. Indian J. Genet. Plant Breed., **83**(2): 270-272.

Source of support: ICAR, Govt. of India

Conflict of interest: None.

Received: Jan. 2023 **Revised:** March 2023 **Accepted:** April 2023

along with three heat tolerant checks, ICCV92944, ICC1205 and ICC4958. The meteorological data, daily maximum and minimum temperature (Fig. 1), the highest average day temp recorded to be above 30°C during pod formation and above 35°C during pod filling stage (Fig. 1). Data on various phenological traits, namely, days to first flowering, days to 50% flowering, days to pod initiation, days to pod filling, and days to maturity, and yield and yield related traits viz., a total number of pods/plant, seed yield per plant, 100 seed weight, plant biomass and harvest index were recorded during non-stress and heat stress condition for both years. The analysis of variance (ANOVA) was performed using GenStat 17th Edition (VSN International, Hemel, Hempstead, UK) for individual environments using mixed model analysis. For each trait and environment, the analysis was performed considering entry, and block nested with replication as random effects and replication as a fixed effect. Broad-sense heritability was calculated as $H^2 = Vg/(Vg + V_e/n_r)$, as suggested by Falconer and Mackay (1996) where H^2 is broad-sense heritability, V_g is genotypic variance, V_e is residual variance, n_r is number of replications.

Analysis of variance indicated significant genetic variability for the studied traits under both non-stress and heat-stress environments for both years (Supplementary Table S2). A wide range of genetic variability for various phenological traits was noted, including days to first flowering ranging from 44 to 74 and 48 to 69 days under non-stress and 43 to 56 and 44 to 59 days under heat stress. Considering yield and yield-related traits, wide range of genetic variability for various yield and yield related traits, including pods/plant (50–77 during 2018 and 53–78 during 2019 under non-stress and 17–29 during 2018 and 14–29 during 2019 under heat stress), biomass (18.24–40 during 2018 and 18.1–35.6 g during 2019 under non-stress condition and 11.7–16.5 during 2018 and 12.77–16.9 g during 2019 under heat stress), seed yield/plant (8.24–19.32 during 2018 and 7.61–17.9 g during 2019 under non-stress condition and 3.9–6.5 during 2018 and 4.4–6.6 g during 2019 under heat stress) were noted. Similarly, wide range of genetic variability for various phenological traits and yield and yield related was recorded in chickpeas (Krishnamurthy et al. 2011; Upadhyay et al. 2011; Gaur et al. 2015), lentils (Sita et al. 2017; El Haddad et al. 2020), cowpea (Hall 2004) and urdbean (Devi et al. 2022) under heat stress environment.

High heritability for days to first flowering (81.7 and 84.9%) (see supplementary Table S2), days to pod initiation (96 and 97%), days to maturity (90.7 and 84.9%), yield plant^{-1} (76 and 66.6%), pod number plant^{-1} (91.1 and 70.4%), and 100 seed weight plant^{-1} (95.6 and 96.5%), as noted in the present study, was also been observed in chickpea (Devi et al. 2022), in lentil (El Haddad et al. 2020), and in urdbean (Chaudhary et al. 2022) under high-temperature environments. As the studied traits showed high heritability, these traits could

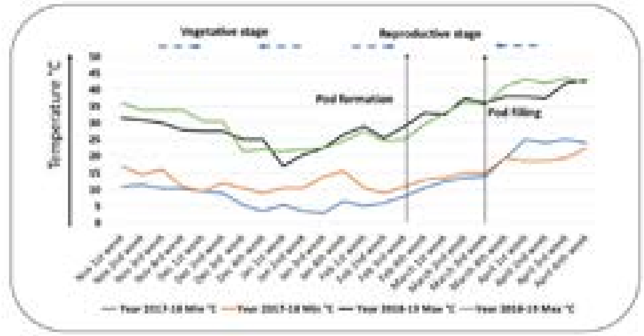

Fig. 1. Weekly mean minimum and mean maximum day temperature during 2017-2018 and 2018-2019

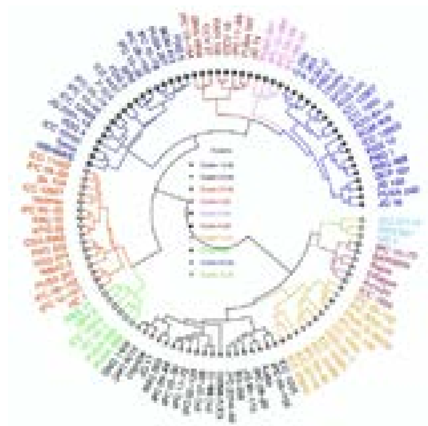

Fig. 2. Cluster analysis of 110 chickpea genotypes evaluated under heat stress during 2017-18

be potentially used to improve chickpeas' heat tolerance. A positive and significant association of days to first flowering was recorded with the days to 50% flowering time, days to pod initiation and days to maturity under heat stress conditions during 2017-18. Similarly, high and positive association of a total number of pods/plant with plant biomass indicated selection of plants with high biomass and number of pods/plant could improve seed yield/plant under heat stress. Similarly, during 2018-2019 under heat stress conditions, days to flower initiation showed a positive and high correlation with days to 50% flowering and days to pod initiation. Positive association of seed yield/plant with number of pods/plant, and harvest index was recorded, while total number of pods/plant also showed a positive and significant correlation with harvest index. Similar findings have been reported in chickpeas under heat stress both under field and controlled environments (Devi *et al.* 2022). Thus, selecting genotypes based on high pods/plant, seed yield/plant and high plant biomass could lead to developing promising heat-tolerant varieties in chickpea.

Cluster analysis was also performed to determine the genetic diversity for yield and yield related traits. All the genotypes were clustered into ten groups for both years under heat stress environment. Fig. 2 indicated that the genotypes, Rajas, Phule G96006, Pusa 267, ICC16919, JG74, Pusa 547, RSG11, GNG1958, IPC12-184 assessed during 2017-18 were well distributed across the clusters and

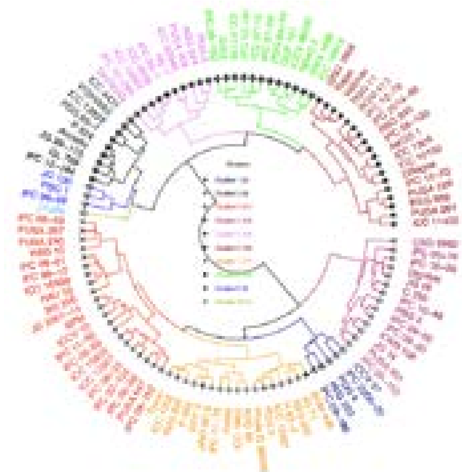

Fig. 3. Cluster analysis of 110 chickpea genotypes evaluated under heat stress during 2018-2019

similarly, Fig. 3 showed that the genotypes, namely, JG74, JAKI9218, P924, IPC06-68, RVG202, RSG931, RSG10, Pusa 240 and GG2 followed the similar pattern of distribution during 2018-19 when evaluated under heat stress environment. The variation recorded in genotypes falling under different clusters as per the evaluation in different year reflected the environmental and genotype interaction., Similarly, type of clustering of genotypes based on yield and yield related traits was noticed by Devi et al. (2022) in chickpeas, in urdbean (Chaudhary et al. 2022) and in lentils (ElHaddad *et al.* 2020) under heat stress environment. The identified heat tolerant and diverse genotypes could be promisingly used as a donor for transferring heat tolerance in to high-yielding and suitable agronomic background but heat-sensitive cultivars for sustaining future chickpea yield under increasing heat stress.

Supplementary material

Supplementary Tables S1 and S2 are provided, www.isgpb.org

Authors' contribution

Conceptualization of research (UCJ); Designing of the experiments (UCJ,YK); Contribution of experimental materials (UCJ, YK); Execution of field/lab experiments and data collection (UCJ,YK); Analysis of data and interpretation (UCJ, YK and PKK); Preparation of the manuscript (UCJ, YK).

Acknowledgment

Financial support from Indian Council of Agricultural Research (ICAR), India is greatly acknowledged.

References

Bhandari K., Sita K., Sehgal A., Bhardwaj A., Gaur P., Kumar S., et al. 2020. Differential heat sensitivity of two cool-season legumes, chickpea and lentil, at the reproductive stage, is associated with responses in pollen function, photosynthetic ability and oxidative damage. J. Agron. Crop Sci., **206**: 734–758.

Chaudhary S., Devi P., Bhardwaj A., Jha U.C., Sharma K.D., Prasad P.V.V., Siddique K.H.M., Bindumadhava H., Kumar S. and Nayyar H. 2020. Identification and Characterization of Contrasting Genotypes/Cultivars for Developing Heat Tolerance in Agricultural Crops: Current Status and Prospects. Front. Plant Sci., **11**: 587264.

Chaudhary S., Jha U.C., Paul, P.J., Prasad P.V., Sharma K., Kumar S., Sen Gupta D., Sharma P., Singh S., Siddique K.H. and Nayyar H. 2022. Assessing the heat sensitivity of Urdbean (*Vigna mungo* L. Hepper) genotypes involving physiological, reproductive and yield traits under field and controlled environment. Front. Plant Sci., 4776.

Devasirvatham V., Gaur P., Mallikarjuna N., Raju T.N., Trethowan R.M. and Tan D.K.Y. 2012. Effect of high temperature on the reproductive development of chickpea genotypes under controlled environments. Funct. Plant Biol., **39**: 1009–1018.

Devasirvatham V., Gaur P., Mallikarjuna N., Raju T.N., Trethowan R.M. and Tan D.K.Y. 2013. Reproductive biology of chickpea response to heat stress in the field is associated with the performance in controlled environments. Field Crops Res., **142**:9–19.

Devi P., Jha U.C., Prakash V., Kumar S., Parida S.K., Paul P.J., Prasad P.V.V., Sharma K.D., Siddique K.H.M. and Nayyar H. 2022. Response of Physiological, Reproductive Function and Yield Traits in Cultivated Chickpea (*Cicer arietinum* L.). Under Heat Stress. Front. Plant Sci., **13**: 880519.

El Haddad, N., Rajendran K., Smouni A., Es-Safi N.E., Benbrahim N., Mentag R., Nayyar H., Maalouf F. and Kumar S. 2020. Screening the FIGS set of lentil (*Lens culinaris* Medikus) germplasm for tolerance to terminal heat and combined drought-heat stress. Agronomy, **10**: 1036.

Falconer D.S. and Mackay T.F.S. 1996. An Introduction to Quantitative Genetics. Longman Group, Essex, UK.

Gaur P.M., Samineni S., Krishnamurthy L., Kumar Shiv., Ghanem M.E., Beebe S., Rao I., Chaturvedi S.K., Basu P.S., Nayyar H., Jayalakshmi V., Babbar A. and Varshney R.K. 2015. High temperature tolerance in grain legumes. Legume Perspective, **7**: 23-24.

Hall A. E. 2004. Breeding for adaptation to drought and heat in cow- pea. European J. Agron., **21**: 447–454.

Hasanuzzaman M., Nahar K., Alam M., Roychowdhury R., and Fujita, M. 2013. Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. Int. J. Mol. Sci., **14**: 9643–9684. doi: 10.3390/ijms14059643.

Krishnamurthy L., Gaur P.M., Basu P.S., Chaturvedi S.K., Tripathi S., Vadez V., Rathore A., Varshney 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 Genet. Res., **9**: 59–69.

Rani A., Devi P., Jha U.C., Sharma K.D., Siddique K.H., and Nayyar H. 2020. Developing climate-resilient chickpea involving physiological and molecular approaches with a focus on temperature and drought stresses. Front. Plant Sci., **10**: 1759.

Sita K., Sehgal A., Kumar J., Kumar S., Singh S., Siddique K. H. *et al.* 2017. Identification of high-temperature tolerant lentil (*Lens culinaris* Medik.) genotypes through leaf and pollen traits. Front. Plant Sci.*,* **8**: 744. doi: 10.3389/ fpls.2017.00744

Upadhyaya H. D., Dronavalli N., Gowda C. L. L. and Singh, S. 2011. Identification and evaluation of chickpea germplasm for tolerance to heat stress. Crop Sci., **51**: 2079–2094.

Supplementary Table S1. A list of genotypes studied

S.no.	Entry Name	Status	Origin/Source
1	PDG 4	Released variety	PAU, Ludhiana, India
2	VISHWAS	Released variety	MPKVV, Rahuri, India
3	BG 256	Released variety	IARI, New Delhi, India
4	GL 769	Released variety	PAU, Ludhiana, India
5	Avrodhi	Released variety	CSAU&T, Kanpur, India
6	PUSA 391	Released variety	IARI, New Delhi, India
7	KWR 108	Released variety	CSAU&T, Kanpur, India
8	RSG 974	Released variety	RAU, Durgapura, India
9	Rajas	Released variety	MPKVV, Rahuri, India
10	GPF 2	Released variety	PAU, Faridkot, India
11	PUSA 547	Released variety	IARI, New Delhi, India
12	NBeG 3	Released variety	Nandiyalindia
13	ICCV 10	Released variety	ICRISAT, Patancheru, India
14	JAKI 9218	Released variety	ICRISAT, Patancheru, India
15	PBG 1	Released variety	PAU, Ludhiana, India
16	HC 1	Released variety	CCSHAU, Hisar, India
17	Tyson	Released variety	Australia
18	GNG 1488	Released variety	Sriganganagar, India
19	CSG 8962	Released variety	Karnal, India
20	C 235	Released variety	India
21	Digvijay	Released variety	MPKVV, Rahuri, India
22	JG 74	Released variety	JNKVV, Jabalpur, India
23	PUSA 209	Released variety	IARI, New Delhi, India
24	RAU 52	Released variety	RAU, Dholi, India
25	PUSA 408	Released variety	IARI, New Delhi, India
26	**ICC 92944(Ch)**	Released variety	ICRISAT, Patancheru, India
27	GCP 101	Released variety	GAU, Junagarh, India
28	AKGS 1	Released variety	Akola, India
29	PUSA 240	Released variety	IARI, New Delhi, India
30	RVG 203	Released variety	Sehore, India
31	JG 130	Released variety	JNKVV, Jabalpur, India
32	Vaibhav	Released variety	IGKVV, Raipur, India
33	RSG 11	Released variety	RAU, Durgapura, India
34	RVG 202	Released variety	Sehore, India
35	BGM 413	Released variety	IARI, New Delhi, India
36	ICCV 96030	Released variety	ICRISAT, Patancheru, India
37	JG 11	Released variety	JNKVV, Jabalpur, India
38	RSG 931	Released variety	RAU, Durgapura, India
39	JG 16	Released variety	JNKVV, Jabalpur, India
40	Chaffa	Released variety	GAU, Junagadh, India
41	PUSA 261	Released variety	IARI, New Delhi, India
42	PDG 3	Released variety	PAU, Ludhiana, India
43	RSG 888	Released variety	RAU, Durgapura, India
44	GNG 1958	Released variety	Sriganganagar, India
45	Phule G 96006	Released variety	MPKVV, India
46	BGM 408	Released variety	IARI, New Delhi, India
47	GG 2	Released variety	GAU, Junagadh, India
48	RSG 10	Released variety	RAU, Durgapura, India
49	PUSA 267	Released variety	IARI, New Delhi, India
50	PDG 5	Released variety	PAU, ludhiana, India
51	KPG 59	Released variety	CSAU&T, Kanpur, India
52	PBG 5	Released variety	PAU, Ludhiana, India
53	ICCV 37	Released variety	ICRISAT, Patancheru, India
54	RSG 945	Released variety	RAU, Durgapura, India
55	IPC 95-1	ABL	IIPR, Kanpur, India
56	IPC 11-72	ABL	IIPR, Kanpur, India
57	IPC 98-12	ABL	IIPR, Kanpur, India
58	IPC 05-59	ABL	IIPR, Kanpur, India
59	IPC 09-50	ABL	IIPR, Kanpur, India
60	IPC 11-55	ABL	IIPR, Kanpur, India
61	IPC 06-68	ABL	IIPR, Kanpur, India
62	IPC 10-48	ABL	IIPR, Kanpur, India
63	IPC 09-153	ABL	IIPR, Kanpur, India
64	IPC 08-100	ABL	IIPR, Kanpur, India
65	IPC 10-181	ABL	IIPR, Kanpur, India
66	IPC 09-58	ABL	IIPR, Kanpur, India
67	IPC 02-120	ABL	IIPR, Kanpur, India
68	IPC 09-59	ABL	IIPR, Kanpur, India
69	IPC 98-51	ABL	IIPR, Kanpur, India
70	IPC 12-284	ABL	IIPR, Kanpur, India
71	IPC 05-74	ABL	IIPR, Kanpur, India
72	IPC 09-35	ABL	IIPR, Kanpur, India
73	IPC 10-78	ABL	IIPR, Kanpur, India
74	IPC 09-102	ABL	IIPR, Kanpur, India
75	IPC 10-73	ABL	IIPR, Kanpur, India
76	IPC 07-56	ABL	IIPR, Kanpur, India
77	IPC 09-186	ABL	IIPR, Kanpur, India
78	IPC 2014-88	ABL	IIPR, Kanpur, India
79	IPC 12-184	ABL	IIPR, Kanpur, India
80	IPC 09-152	ABL	IIPR, Kanpur, India
81	JG 99-115	ABL	IIPR, Kanpur, India
82	IPC 2000-20	ABL	IIPR, Kanpur, India
83	JG 2001-14	ABL	JNKVV, Jabalpur, India
84	IPC 09-20	ABL	IIPR, Kanpur, India
85	IPC 10-28	ABL	IIPR, Kanpur, India
86	**ICC 4958 (Ch)**	Landrace	ICRISAT, Patancheru, India
87	PDG 84-10	landrace	India
88	ICC 07110	Landrace	ICRISAT, Patancheru, India
89	ICC 12907	landrace	ICRISAT, Patancheru, India
90	**ICC 1205(Ch)**	Landrace	ICRISAT, Patancheru, India

91	H 82-2	Landrace	India
92	Katila	Landrace	India
93	PDG 85-1	Landrace	India
94	P 924	Landrace	India
95	P 363	landrace	India
96	ICC 07118	Landrace	ICRISAT, Patancheru, India
97	ICC 10150	Landrace	ICRISAT, Patancheru, India
98	ICC 1882	Landrace	ICRISAT, Patancheru, India
99	Dillagee	Landrace	India
100	BARWAN	Landrace	India
101	BPM	Landrace	India
102	ICC 12928	Landrace	ICRISAT, Patancheru, India
103	ICC 12921	Landrace	ICRISAT, Patancheru, India
104	ICC 11452	Landrace	ICRISAT, Patancheru, India
105	ICC 4431	Landrace	ICRISAT, Patancheru, India
106	ICC 16919	Landrace	ICRISAT, Patancheru, India
107	ICC 15925	Landrace	ICRISAT, Patancheru, India
108	ICC 1304	Landrace	ICRISAT, Patancheru, India
109	ICC 15663	Landrace	ICRISAT, Patancheru, India
110	ICC 10489	Landrace	ICRISAT, Patancheru, India

ABL= Advanced breeding line

Supplementary Table. S2. Variance components due to genotypes (σ^2) and their standard error (SE) for various traits evaluated under non stress and heat stress

Environment during 2017-18 and 2018-2019

Traits	2017 normal (non-stress) condition					2018 normal (non-stress) condition				
	Genetic variance	SE	Range	Mean	Heritability(%)	Genetic variance	SE	Range	Mean	Heritability(%)
Days to first flowering	42.3**	6.1	44.5-74.9	64.2	98.49	22.1**	3.4	43-56.3	50.9	90.57
Days to 50% flowering	36.3**	5.2	51.1-82.1	72.3	98.24	28.9**	4.5	51.1-62.5	56.3	91.31
Days to pod initiation	38.8**	5.5	62.6-98.7	83.2	98.73	18.3**	2.9	58.2-72.5	66.2	90.15
Days to pod filling	2.1**	0.4	20-25.5	22.8	75	0.9**	0.2	12.6-16.7	14.2	51.43
Number of pods/plant	39.1**	7.7	50-77	61.7	74.05	31.1**	5.9	16.5-29.4	23	76.23
Days to maturity	10.3**	1.5	104-126.9	121.4	95.81	4.6**	0.8	87-99.4	94.3	80.7
Plant height (cm)	41.2**	6	36.2-65.7	51.1	97.17	40.8**	5.9	21.88-47.6	35.7	97.49
Biomass (g)	24.8**	3.7	18.24-40	27.4	94.48	14.9**	2.8	11.7-16.5	14.2	77
Seed yield/plant (g)	6.3**	1	8.24-19.32	14.1	90.65	5.2**	0.97	3.91-6.5	5.2	78.2
Hundred seed weight (g)	15.5**	2.2	10.4-27.9	19.1	99.68	17.9**	2.6	11.2-26.4	17.8	98.08
Harvest index (%)	27.13**	4.6	43.5-65.8	52.9	83.27	20.1**	3.5	24.9-48.6	36.9	81.05
	2018 heat stress condition					2019 heat stress condition				
	Genetic variance	SE	Range	Mean	Heritability(%)	Genetic variance	SE	Range	Mean	Heritability(%)
Days to first flowering	8.5**	1.5	47.8-68.8	61.2	81.73	12.11**	1.9	44.3-59.36	52.6	84.92
Days to 50% flowering	7.2**	1.3	55.6-82.5	71	79.12	19.1**	2.7	51.1-70.1	60.9	98.23
Days to pod initiation	10.1**	1.5	70-94.8	81	96.19	19.3**	2.8	60.7-78.4	70.1	97.08
Days to pod filling	1**	0.19	21-24	22.9	76.92	2.9**	0.5	13.4-21.5	17.2	81.69
Number of pods/plant	8.2**	1.3	53.1-78.4	62	91.11	10.85**	2.2	14.8-28.8	22.7	70.45
Days to maturity	6.9**	1	118.4-128.5	123	90.79	6.2**	1	89.2-106.7	100.4	84.93
Plant height (cm)	31**	4.8	43.2-70	57	92.12	14.3**	2.1	29.9-45.3	37.9	96.95
Biomass (g)	1.33**	0.3	18.1-35.65	25.04	68.21	1.05**	0.2	12.7-16.8	14.9	59.32
Seed yield/plant (g)	0.38**	0.05	7.61-17.9	13.58	76	0.2**	0.05	4.4-6.63	5.3	66.67
Hundred seed weight (g)	14.2**	2.1	11.3-30.1	30.1	95.69	16.1**	2.3	12.5-29.5	19.9	96.52
Harvest index (%)	27.9**	4.77	44.5-62.8	62.8	82.22	14.8**	3.2	26.9-45.4	35.5	68.36

** significant at 1%