Estimation of Heritability, Genetic Advance and Correlation for Quantitative Traits in M3-Generation Chickpea (*Cicer arietinum* L.) under Induced EMS Mutagenesis

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Received:- 08 April 2025/ Revised:- 14 April 2025/ Accepted:- 25 April 2025/ Published: 30-04-2025

***Abstract*—** *An experiment was carried out with two varieties of chickpea-IC265291 (V1) and IC265298 (V2) which were obtained from NBPGR, New Delhi to study the Heritability, correlation and Genetic advance as percent of the mean for 11 quantitative characters. Healthy & Uniform seeds of two varieties of chickpea were treated with different concentrations of chemical mutagen EMS (Ethyl Methyl Sulfonate) viz:0.1%, 0.2%, 0.3%, 0.4%, 0.5% and 0.6%.The seeds were grown in petri plates and seed survival rate and seedling characters were studied. The EMS-treated seeds along with the control (untreated) seeds were sown in the field at CPMB (Centre for Plant Molecular Biology), Osmania University, Hyderabad. The result of the study, revealed that all the characters under study were shown significant phenotypic and genotypic correlations with seed weight except days to flower initiation, days to 50% flowering and days to pod maturity. In Chickpea, Phenotypic Coefficient of Variation (PCV) for all the traits is found to be higher than Genotypic Coefficient of Variation (GCV).For the traits Number of branches per plant, Number of pods per plant, Pod weight per plant, Number of seeds per plant and 100 seed weight-Heritability(h^2) and Genetic Advance(GA) are found to be higher. These are the most important traits that can be utilised for the improvement of seed yield in chickpea.*

***Keywords*— Chickpea, Heritability, Genetic Advance, Correlation, Induced EMS.**

I. INTRODUCTION

The chickpea, known scientifically as *Cicer arietinum*, is an annual legume in the *Fabaceae* family cultivated for its edible seeds. This plant features a branched stem that can be straight or slightly bent, adorned with small feathery leaves that grow alternately along the stem. Chickpea are an abundant and affordable source of protein, which can aid individuals in enhancing the nutritional value of their diets, thereby playing an important role in food security in developing nations.(Kumar et al., 1900).It offers significant benefits for individuals with diabetes and provides a rich supply of essential nutrients including vitamins A, C, E, K, B1–B3, B5, B6, B9, as well as minerals like iron, zinc, magnesium, and calcium, all of which contribute positively to human health.(Koul et al., 2022).Chickpeas are a significant legume cultivated across approximately 18 million hectares globally, serving as an essential dietary source for many people in semiarid tropical regions and contributing greatly to the sustainable productivity of farming systems (Vadez et al., 2021). Chickpeas (*Cicer arietinum* L.) are a significant pulse crop cultivated and eaten globally, particularly in countries across Africa and Asia. They provide a substantial amount of carbohydrates and protein, with the quality of protein being regarded as superior to that of other pulses (Jukanti et al., 2012). Chickpea (*Cicer arietinum* L.), which includes both desi and kabuli types, is a cherished pulse crop around the world. Its cultivation takes place in more than fifty countries, ranging from the Indian subcontinent and southern Europe to the Middle East, North Africa, the Americas, Australia, and China. Comprising 80% of its dry seed mass, chickpea is rich in carbohydrates and protein, and it is recognized for its various health advantages, earning it the designation of a 'functional food' (Zhang et al., 2024). Mutation breeding serves as a valuable method for generating genetic diversity in chickpea cultivation, given its self-pollinating characteristics and limited genetic diversity (Dinkar et al., 2020). Ethyl methane sulfonate (EMS) mutagenesis serves as an effective method for creating genetic resources that help uncover underexplored genes and analyse gene functions to gain insights into the molecular foundation of significant agronomic traits (Chen et al., 2022). Both physical and chemical agents can be utilized to generate mutations in advanced plant species. Among the physical agents, gamma rays are favored in higher plants because of their ability to penetrate deeply, while among the chemical agents, ethyl methane sulphonate (EMS) is chosen for its capability to cause a high frequency of mutations that are irreversible (Journal et al., 2019). Chemical mutagenesis offers a cost-effective, straightforward, and convenient method for generating allelic variation in the genomes of plants and animals. Various chemical mutagens induce distinct forms of DNA damage, including alkylating agents and azides (Subramaniam & Kumar, 2023). The genetic improvement of any crop largely relies on the genetic diversity available within the population, while germplasm acts as an important reservoir of base population and offers a source of extensive variability (Shedge et al., 2019). Any breeding program's ability to succeed is largely dependent on the population's genetic diversity (Ene et al., 2016). Heritability examines the connection between genotypic variance and the underlying true genotypic values of observed and phenotypic variance (Turk, n.d.). The level of gain achieved in a character under a specific selection pressure is explained by genetic advancement. High estimates of heritability combined with high genetic advancement provide the ideal environment for selection. Additionally, it shows that the trait contains additive genes, which further suggests that selecting for such qualities will result in dependable crop development (Mofokeng et al., 2019). The term "heritability" refers to the degree to which genetic variation accounts for a trait's variation. (Estimating Trait Heritability Learn Science at Scitable, n.d.). Genetic advance and heritability aid in assessing how the environment affects character expression and how much improvement is feasible following selection (Sriraj & Gurjar, 2022).

II. MATERIALS & METHODS

Two chickpea genotypes IC265291 (V1) and IC265298 (V2) were collected from NBPGR, New Delhi. These seeds were soaked in distilled water and they were treated with different concentrations of EMS (mutagen) viz; 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.6% and excess of the EMS is removed by thorough washing the seeds with distilled water. Seeds were kept in triplicate in petriplates for germination study. On the 5th day, seed germination was observed with the emergence of cotyledon leaf. Germination percentage and Seed survival was worked out for each accession separately. The treated seeds and untreated (Control) forms the M0-Generation which were sown in the pots in CRBD pattern. In each row of 10m length, 10 plants were maintained with 10cm space between them. In between 2 rows, 30cm space was maintained. The observations were recorded on Height of the plant (cm), Number of Branches (per plant), Days for Initial Flowering, Days for 50% Flowering, Days for Pod Maturity, Number of Pods per Plant, Pod weight per Plant, Number of Seeds per Pod, Number of Seeds per Plant, Seed Weight (in gm per plant) and 100 Seeds weight (in gm).The mutagenized first generation-M1 plants were self-pollinated to raise M2-generation.In M2-genetaion the high seed yield plants were harvested separately and their seeds were sown in the field to raise M3-generation.In M3-generation Seed Yield and Yield contributing characters were recorded. In accordance with Panse and Sukhatme (1967), the statistical analysis and variance resulting from various sources were calculated. Genotypic Coefficient of Variation & Phenotypic coefficient of variation were computed using Burton's (1952) recommended methodology. Broad Sense Heritability & Genetic Advance as percentage of means were estimated as suggested by Jhonson et al. (1955).

III. RESULTS AND DISCUSSION

TABLE 1
PHENOTYPIC CORRELATION FOR QUANTITATIVE TRAITS WITH SEED YIELD IN CHICKPEA IN M3 GENERATION UNDER EMS INDUCED MUTAGENESIS

No.	Character	1 Pl. Ht	2 P.Br/pl	3 Days to F. Ini	4 Days to 50% F	5 Days to P.M	6 No. of P/pl	7 Pod. Wt (g/pl)	8 No. of S/Pod	9 No. of S/pl	10 100 S. wt (g/pl)	11 S. wt (g/pl)
1	Pl. Ht	1.000	0.965**	-0.925**	-0.916**	-0.885**	0.562**	0.957**	0.953**	0.963**	0.958**	0.906**
2	P.Br/pl		1.000	-0.900**	-0.900**	-0.850**	0.933**	0.916**	0.935**	0.943**	0.937**	0.885**
3	Days to F. Ini			1.000	0.990**	0.978**	-0.978**	-0.965**	-0.945**	-0.976**	-0.978**	-0.957**
4	Days to 50% F				1.000	0.980**	-0.970**	-0.952**	-0.946**	-0.973**	-0.976**	-0.961**
5	Days to P.M					1.000	-0.963**	-0.963**	-0.919**	-0.956**	-0.949**	-0.944**
6	No. of P/pl						1.000	0.991**	0.960**	0.986**	0.981**	0.953**
7	Pod. Wt (g/pl)							1.000	0.937**	0.969**	0.960**	0.938**
8	No. of S/Pod								1.000	0.982**	0.954**	0.934**
9	No. of S/pl									1.000	0.995**	0.971**
10	100 S. wt (g/pl)										1.000	0.972**

Pl.ht- Plant height (cm); Br/pl- Number of branches per plant; Days F.Ini- Days to flower initiation; Days 50% F- days to 50% of flowering; Days to P.M.-Days to pod maturity; No.of P/Pl- Number of pods per plant; Pod.Wt/Pl(g)- pod weight per plant (g); No.of S/pl-Number of seeds per plant; Seed.Wt (g/Pl)- seed weight per plant (g); 100 S.wt(g)- 100 seed weight (g).

In M3-generation, the phenotypic correlation analysis revealed that the trait correlated significantly for seed weight per plant (in gm) with plant height (in cm) 0.906**, Number of branches (per plant) 0.885**, Number of pods (per plant) 0.953**, pod weight (in gm per plant) 0.935**, Number of seeds (per plant) 0.954**, 100 seed weight (in gm per plant) 0.972** and negatively phenotypically correlated with the traits number of days for initial flowering -0.957**, number of days for 50% flowering -0.961**, number of days taken for pod maturity -0.954**.The trait 100 seed weight (in gm per plant), phenotypically correlated positively with the traits plant height (in cm) 0.955**, number of branches (per plant) 0.937**, number of pods (per plant) 0.981**, pod weight (in gm per plant) 0.960**, number of seeds (per pod)0.984**, number of seeds (per plant) 0.995**and negatively phenotypically correlated with the traits number of days for initial flowering -0.978**, number of days for 50% flowering -0.975**, number of days taken for pod maturity -0.949**.The trait number of seeds per plant correlated positively for the traits plant height (in cm) 0.963**, Number of branches (per plant) 0.945**, Number of pods (per plant) 0.986**, pod weight (in gm per plant) 0.969**, Number of seeds (per pod) 0.982** and negatively phenotypically correlated with the traits number of days for initial flowering -0.976**, number of days for 50% flowering -0.975**, number of days taken for pod maturity -0.956**.The quantitative character number of seeds per pod positively correlated with plant height (in cm) 0.953**, number of branches per plant 0.935**, number of pod (per plant) 0.960**, pod weight (in gm per plant) 0.937** but negatively correlated with the traits number of days for initial flowering -0.945, number of days for 50% flowering -0.946**, number of days taken for pod maturity -0.915**.The phenotypic character Pod weight (in gm per plant) correlated positively with plant height (in gm) 0.957**, number of branches (per plant) 0.916**, number of pods (per plant) 0.991** and negatively correlated with the traits number of days for initial flowering -0.965**, number of days for 50% flowering -0.952**, number of days taken for pod maturity -0.963.The character number of pods (per plant) is positively correlated with the traits plant height (in cm) 0.962** and number of branches (per plant) 0.939** but negatively correlated with the number of days for initial flowering -0.978**, number of days for 50% flowering -0.970**, number of days taken for pod maturity -0.963**.The trait number of days taken for pod maturity is positively correlated with the traits the number of days (taken for initial flowering) 0.978** , number of days taken for 50% flowering 0.980** but negatively correlated with the trait plant height (in cm) -0.885** and the trait number of branches (per plant) -0.850**.The quantitative character number of days taken for 50% flowering is positively correlated with number of days taken for initial flowering 0.990**and it is negatively correlated with plant height (in cm) -0.916** and number of branches per plant -0.900**.The trait number of days for flower initiation is correlated negatively with the trait plant height (in cm) and number of branches (per plant) -0.925** and -0.900** respectively. The trait number of branches per plant is positively correlated with the trait plant height (in cm) 0.965**.

TABLE 2
GENOTYPIC CORRELATION FOR QUANTITATIVE TRAITS WITH SEED YIELD IN CHICKPEA IN M3 GENERATION UNDER EMS INDUCED MUTAGENESIS

No.	Character	1 (Pl. Ht)	2 (P.Br/pl)	3 (Days to F. Ini)	4 (Days to 50% F)	5 (Days to P.M)	6 (No. of P/pl)	7 (Pod. Wt)	8 (No. of S/Pod)	9 (No. of S/pl)	10 (100 S. wt)	11 (S. wt)
1	Pl. Ht	1.000	0.968**	-0.928**	-0.917**	-0.858**	0.963**	0.958**	0.972**	0.968**	0.961**	0.937**
2	P.Br/pl		1.000	-0.905**	-0.904**	-0.855**	0.943**	0.919**	0.961**	0.955**	0.946**	0.924**
3	Days to F. Ini			1.000	0.991**	0.981**	-0.958**	-0.970**	-0.970**	-0.964**	-0.968**	-0.995**
4	Days to 50% F				1.000	0.983**	-0.972**	-0.954**	-0.970**	-0.958**	-0.928**	-0.979**
5	Days to P.M					1.000	-0.965**	-0.963**	-0.935**	-0.961**	-0.955**	-0.985**
6	No. of P/pl						1.000	0.991**	0.981**	0.991**	0.983**	0.968**
7	Pod. Wt (g/pl)							1.000	0.960**	0.975**	0.966**	0.966**
8	No. of S/Pod								1.000	0.994**	0.997**	0.984**
9	No. of S/pl									1.000	0.997**	0.990**
10	100 S. wt (g/pl)										1.000	0.997**

Pl.ht- Plant height (cm); Br/pl- Number of branches per plant; Days F.Ini- Days to flower initiation; Days 50% F- days to 50% of flowering; Days to P.M.-Days to pod maturity; No.of P/Pl- Number of pods per plant; Pod.Wt/Pl(g)- pod weight per plant (g); No.of S/pl-Number of seeds per plant; Seed.Wt (g/Pl)- seed weight per plant (g); 100 S.wt(g)- 100 seed weight (g).

In M3-generation, the genotypic correlation data analysis revealed that the trait seed weight per plant was highly significant genotypically correlation with plant height (cm) 0.937**, number of branches per plant 0.924**, number of pods per plant 0.986**, pod weight per plant 0.966**, number of seeds per pod 0.984**, number of seeds per plant 0.997**, 100 seed weight per plant 0.997** but it was observed that the seed weight recorded highly negative genotypically correlated with days to flower initiation -0.995**, days to 50% flowering -0.997**, days to pod maturity-0.985**.It also revealed that the trait plant height was highly significant genotypically correlation with branches per plant 0.968**, number of pods per plant 0.963**, pod weight per plant 0.958**, number of seeds per pod 0.972**, number of seeds per plant 0.968**, 100 seed weight per plant 0.961**, seed weight per plant 0.937**, but it was observed that plant height was highly negative genotypically correlated with days to flower initiation -0.928**, days to 50% flowering -0.917**, days to P.M -0.888**.The trait number of branches per plant was highly significant genotypically correlation with number of pods per plant 0.943**, pod weight per plant 0.919**, number of seeds per pod 0.961**, number of seeds per plant 0.955**, 100 seed weight per plant 0.946**, seed weight per plant 0.924**, but it was observed that number of branches per plant days to flower initiation -0.905**, days to 50% flowering -0.904**, days to P.M -0.855**.The trait number of days to flower initiation was highly significant genotypically correlation with days to 50% flowering 0.991**, days to P.M 0.981**, but it was observed that days to flower initiation was highly negative genotypically correlated with number of pods per plant -0.982**, pod weight per plant -0.970**, number of seeds per pod -0.970**, number of seeds per plant -0.984**, 100 seed weight per plant -0.986**, seed weight per plant (g) -0.995**.The statistical analysis results revealed that the trait days to 50% flowering was highly significant genotypically correlation with days to pod maturity 0.983**, but it was observed that days to 50% flowering was highly negative genotypically correlated with number of pods per plant -0.972**, pod weight per plant -0.954**, number of seeds per pod -0.970**, number of seeds per plant -0.982**, 100 seed weight per plant -0.982**, seed weight per plant (g) -0.997**.The trait number of days taken to pod maturity was highly negative genotypically correlated with number of pods per plant -0.965**, pod weight per plant -0.965**, number of seeds per pod -0.935**, number of seeds per plant -0.961**, 100 seed weight per plant -0.955**, seed weight per plant (g) -0.985**.The trait number of pods per plant was highly significant genotypically correlation with pod weight per plant 0.991**, number of seeds per pod 0.981**, number of seeds per plant 0.991**, 100 seed weight per plant 0.987**, seed weight per plant (g) 0.986**. The trait pod weight per plant was highly significant genotypically correlation with number of seeds per pod 0.960**, number of seeds per plant 0.975**, 100 seed weight per plant 0.966**, seed weight per plant (g) 0.966**.The trait number of seeds per pod was highly significant genotypically correlation with number of seeds per plant 0.994**, 100 seed weight per plant 0.997**, seed weight per plant (g) 0.984**.The trait number of seeds per plant was highly significant genotypically correlation with 100 seed weight per plant 0.997**, seed weight per plant (g) 0.997**.The correlation statistical analysis results revealed that the trait 100 seed weight per plant (g) was highly significant genotypically correlation with seed weight per plant (g) 0.997**, in our study.

TABLE 3
ESTIMATION OF HERITABILITY, GCV AND PCV, GENETIC ADVANCE AND GENETIC ADVANCE VALUE % MEANS

S.No	Characters	Heritability (%)	Genotypic Coefficient of Variations	Phenotypic Coefficient of Variations	Genetic Advance	Genetic Advance value % means
1	**Pl. Ht**	99.677	18.584	18.615	12.209	38.219
2	**P.Br/pl**	99.104	28.634	28.763	5.927	58.721
3	**Days. F.Ini**	99.398	12.012	12.049	9.229	24.671
4	**Days to 50% F**	99.616	12.413	12.436	10.560	25.521
5	**Days to P.M**	99.793	6.450	6.457	11.520	13.274
6	**No.of P/pl**	99.823	39.283	39.318	26.260	80.851
7	**Pod.Wt/pl(g)**	99.804	40.235	40.275	14.654	82.803
8	**No.of S/Pod**	95.543	19.238	19.681	0.572	38.737
9	**No.of S/pl**	99.162	49.657	49.866	50.156	101.863
10	**100 S. wt(g)**	98.961	49.580	49.839	12.184	101.603
11	**S. wt(g/pl)**	93.579	16.948	17.520	6.762	33.774

Pl.ht- Plant height (cm); Br/pl- Number of branches per plant; Days F.Ini- Days to flower initiation; Days 50% F- days to 50% of flowering; Days to P.M.-Days to pod maturity; No.of P/Pl- Number of pods per plant; Pod.Wt/Pl(g)- pod weight per plant (g); No.of S/pl-Number of seeds per plant; Seed.Wt (g/Pl)- seed weight per plant (g); 100 S.wt(g)- 100 seed weight (g).

3.1 Estimation of Heritability, GCV and PCV, Genetic advance and Genetic advance value % Means:

In M3-Generation, the Phenotypic Coefficient of Variation (PCV) recorded for the character plant height is 18.615, and the Genotypic Coefficient of Variation observed is 18.548.Heritability estimation recorded is 99.677 and Genetic Progress is 38.219 percent above the norm. The PCV recorded for number of branches per plant is 28.763 and the GCV was observed as 28.634.Heritability is observed as 99.104 and genetic progress as 58.721.The PCV and GCV values for number of days for flower initiation is 12.049 and 12.012 respectively. The observed genetic progress as a percent of mean is 24.671 percent and the heritability estimation is 99.398.The observed PCV value is 12.436 and the GCV is 12.413.Heritability estimates is found to be 99.616 and genetic advance is 25.521 percent of the mean. The PCV and GCV for the trait number of days for pod maturity is 6.457 and 6.540 respectively. Heritability estimates is 99.793 and genetic progress value is 13.274 percent of the mean. The phenotypic coefficient of variation for the trait number of pods per plant is 39.318 and the genotypic coefficient of variation is 39.283.The genetic improvement as a percent of mean is 80.851 and the heritability is 99.823.For the trait pod weight per plant, the phenotypic coefficient of variation and genotypic coefficient of variation values are 40.275 and 40.235 respectively. Heritability is observed as 99.804 and genetic progress as 82.803 percent above the norm. The PCV and GCV values for the trait number of seeds per pod is 19.681 and 19.238 respectively. Heritability estimations is found to be 95.543 and genetic progress is found to be 38.737 percent of the mean. The phenotypic coefficient of variation (PCV) value observed for the character number of seeds per plant is 649.866 and the genotypic coefficient of variation (GCV) is 49.657.Heritability estimation value is 99.162 and the genetic progress observed is 101.863 percent of the mean. The phenotypic coefficient of variation observed for the trait 100 seed weight per plant is 49.839 and the genotypic coefficient of variation observed is 49.580.The observed genetic progress as the percent of the mean is 101.603 and the heritability estimates are 98.961.The phenotypic coefficient of variation and the genotypic coefficient of variation recorded is 17.520 and 16.948 respectively. Genetic progress is 33.774 percent above the norm and the heritability estimation is 93.579.

TABLE 4
PHENOTYPIC AND GENOTYPIC CORRELATION OF THE TRAITS WITH SEED YIELD IN M3 GENERATION

	Phenotypic Correlation	Genotypic Correlation
Traits	**Seed weight/pl**	
Pl. Ht	0.906**	0.937**
P.Br/pl	0.885**	0.924**
Days to F.Ini	-0.957**	-0.995**
Days to 50% F.	-0.961**	-0.997**
Days to P.M.	-0.954**	-0.985**
No.of P/pl	0.953**	0.986**
Pod.Wt (g/pl)	0.935**	0.966**
No.of S/Pod	0.954**	0.984**
No.of S/pl	0.971**	0.997**
100 S. wt (g/pl)	0.972**	0.997**

Pl.ht- Plant height (cm); Br/pl- Number of branches per plant; Days F.Ini- Days to flower initiation; Days 50% F- days to 50% of flowering; Days to P.M.-Days to pod maturity; No.of P/Pl- Number of pods per plant; Pod.Wt/Pl(g)- pod weight per plant (g); No.of S/pl-Number of seeds per plant; Seed.Wt (g/Pl)- seed weight per plant (g); 100 S.wt(g)- 100 seed weight (g).

The correlation analysis results revealed that all the traits except Days to initiation of flowering, Days to 50% flowering and Days to pod maturity were shown significant phenotypic and genotypic possitive correlations with seed weight. The most yield contributing traits such as pods per plant, seeds per plant and 100 seed weight showed significant positive correlation with seed yield in blackgram earlier by Bhattu et al., 2023.

TABLE 5
ESTIMATION OF HERITABILITY, GCV AND PCV, GENETIC ADVANCE AND GENETIC ADVANCE VALUE % MEANS

S.No	Characters	Heritability (%)	Genotypic Coefficient of Variations	Phenotypic Coefficient of Variations	Genetic Advance	Genetic Advance value % means
1	**No.of P/pl**	99.823	39.283	39.318	26.26	80.851
2	**Pod.Wt/pl(g)**	99.804	40.235	40.275	14.654	82.803
3	**No.of S/pl**	99.162	49.657	49.866	50.156	101.863
4	**100 S. wt(g)**	98.961	49.58	49.839	12.184	101.603

No.of P/Pl- Number of pods per plant; Pod.Wt/Pl(g)- pod weight per plant (g); No.of S/pl-Number of seeds per plant; 100 S.wt(g)- 100 seed weight (g).

In our study, the heritability and genetic advance (GA) was found higher for majority of the characters. It can be concluded that number of pods per plant, number of seeds per plant, pod weight, seed weight and 100 seed weights are most important traits in chickpea which can be used for the improvement of seed yield. Phenotypic coefficients of variation (PCV) is little higher than the genotypic coefficients of variation (GCV) for all the traits under study in chickpea mutant. It reveals that no environmental effect or very little environmental influence on selected characters in our mutants (Table). Similar results were found with work of Bhattu et al., 2023 in blackgram.

IV. CONCLUSION

All the traits except Days to initiation of flowering, Days to 50% flowering and Days to pod maturity were shown significant phenotypic and genotypic correlations with seed weight. Phenotypic coefficients of variation (PCV) is higher than the genotypic coefficients of variation (GCV) for all the traits under study in chickpea mutant. Heritability and Genetic Advance (GA) was found higher for majority of the characters. It can be concluded that number of pods per plant, number of seeds per plant, pod weight, seed weight and 100 seed weights are most important traits in chickpea which can be used for the improvement of seed yield.

ACKNOWLEDGEMENT

This is a part of my Ph.D work and I am extremely grateful to Department of Genetics & Biotechnology, Osmania University, Hyderabad for providing the field and laboratory facilities for conducting experiments. I also acknowledge NBPGR, New Delhi for providing seed material of chickpea genotypes.

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