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Genetic variability and association among various traits in chickpea (*Cicer arietinum*) mutants

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Abstract

M_3 generation of chickpea obtained through mutagenesis by EMS, gamma rays and combination of both, was evaluated for variability with respect to ten traits *viz*., days to 50 per cent flowering, days to maturity, plant height, primary branches per plant, pods per plant, seeds per pod, biological yield per plant, harvest index, seed yield per plant and 100 seed weight. Sufficient genetic variability was observed for seed yield and related traits. Further, the association of these traits with yield was evaluated to facilitate indirect selection. Correlation studies revealed that seed yield per plant had a positive and significant association with pods per plant, seeds per pod, harvest index and 100-seed weight. High genetic advance coupled with high heritability estimates observed for biological yield per plant, seeds per pod, 100 seed weight and seed yield per plant indicated the predominance of additive gene action in the inheritance of these characteristics.

Key words: Chickpea, EMS, Gamma rays, M_3, Mutation, Variability

Currently the productivity of chickpea is very low and has been stagnant in recent years. Despite high morphological variability, genetic variation in chickpea is limited probably due to its monophyletic descendence from *Cicer reticulatum* (Ladizinsky and Adler 1976; Lev-Yadun *et al*. 2000; Abbo *et al*. 2003, Boparai and Katna 2021). A narrow genetic base, due to the bottlenecks associated with its evolution and domestication, as well as due to the replacement of locally adapted crop landraces by the genetically advanced modern varieties, is the main reason behind the lacuna. Induced mutagenesis with the discovery of an array of mutagens and improved treatment methodologies offers huge possibilities for the induction of desired changes in various attributes, which can be exploited as such or through recombination breeding. It also enriches the germplasm with the newly arisen and hitherto unknown genotype. Through mutagenesis, it is possible to change one or few undesirable traits without drastically altering otherwise superior agronomic base. The two mutagens acting in a sequence one after the other may produce more than an additive effect, if the sites not affected by the first are exposed to the action of the second. On the other hand, if two mutagens merely compete for the same site, or if their actions are independent, the results obtained will be additive or less than additive, such studies besides enhancing or reducing mutation frequency, also help in fixing most effective combination treatments (Astveik1967).

Keeping this in mind a mutation breeding programme was initiated using one well adapted chickpea variety 'HPG-17' and two mutagens namely, EMS and gamma rays and their combined treatments. This paper discusses the outcome of selected (on the basis of yield and ascochyta blight resistance) M_2 plants growing as M_3 screened for variability and further analysed for identification of important traits associated with high yield.

Materials and Methods

The experimental material in the present study included 240 M_3 mutants derived from chickpea variety HPG-17 using EMS, gamma rays and their combinations (Sharma *et al.* 2019; Table 1). The experiment was laid out in Augmented Block Design with three checks namely, PG 0027, GPF-2 and HPG-17 (untreated) in the Department of Genetics and Plant Breeding, CSK HPKV Palampur, H.P. The recommended package of practices was followed during the layout and conduct of the trial with row to row 30 cm and plant to plant 10 cm spacing. The data were recorded from five randomly selected plants per treatment or genotype. The data from all five plants were pooled to calculate the average. Traits evaluated were days to 50 per cent flowering, days to maturity, plant height, primary branches per plant, pods per plant, seeds per pod, biological yield per plant, harvest index, seed yield per plant and 100 seed weight. Analysis of variance was carried out as per Federer (1955). Parameters of variability were calculated as per Burton and De Vane (1953) and correlation coefficients as per Al-Jibouri *et al.* (1958) and Dewey and Lu (1959).

Result and Discussion

Analysis of variance for experimental design

The analysis of variance (ANOVA) revealed no significant differences among the blocks (eliminating treatments) and all treatments were significantly different from each other when the effect of the block was eliminated (Table 2). Variations among checks were observed only in seed yield per plant, 100 seed

Table 1. Detail of nature of treatments and the number of plants studied within each treatment

Sr. No.	Treatment	Mutagen	Number of Plants
1	100 Gy (T1)	Gamma-rays	45
2	150 Gy (T2)	Gamma-rays	32
3	200 Gy (T3)	Gamma-rays	64
4	300 Gy (T4)	EMS	13
5	0.05% (T5)	EMS	7
6	0.10% (T6)	EMS	4
7	0.15% (T7)	EMS	8
8	200 Gy + 0.05% (T8)	Combination of EMS and gamma-rays	9
9	200 Gy + 0.10% (T9)	Combination of EMS and gamma-rays	14
10	200 Gy + 0.15% (T10)	Combination of EMS and gamma-rays	7
11	300 Gy + 0.05% (T11)	Combination of EMS and gamma-rays	14
12	300 Gy + 0.10% (T12)	Combination of EMS and gamma-rays	10
13	300 Gy + 0.15% (T13)	Combination of EMS and gamma-rays	13
14	Control : 3 (PG 0027, HPG-17 & GPF-2)		240

Table 2. Analysis of variance (ANOVA) in chickpea

Traits	Block		Treatment		Checks	Varieties	Checks vs. Varieties	Error
	Ignoring treatments	Eliminating treatments	Ignoring blocks	Eliminating blocks				
df	11	11	242	242	2	239	1	28
Days to 50 per cent flowering	41.96*	10.44	29.12*	27.69*	1.97	29.41*	14.20	5.54
Days to 75 per cent maturity	4.57	6.34	21.48*	21.56*	0.56	18.77	710.07*	11.24
Plant height (g)	44.03*	1.61	18.33*	16.4*	2.81	12.02*	1556.58*	2.6
Primary branches per plant	0.58*	0.02	0.16*	0.13*	0.005	0.16*	1.00*	0.04
Pods per plant	13.42*	1.47	12.24*	11.69*	0.24	10.58*	432.98*	1.48
Seeds per pod	0.01*	0.003	0.06*	0.06*	0.002	0.06*	0.02*	0.002
Biological yield per plant (g)	133.79*	2.25	52.75*	46.77*	2.73	53.03*	86.72*	3.62
Seed yield per plant (g)	3.73*	0.48	6.93*	6.78*	140.32*	5.28*	133.08*	0.29
100 seed weight (g)	1.6	3.72	23.96*	24.06*	888.18*	3.87	3097.05*	2.42
Harvest index (per cent)	79.54*	7.97	89.06*	85.81*	1265.6*	75.16*	1059.59*	5.89

* Significant at $p \leq 0.05$

weight and harvest index. Tested genotypes expressed considerable variation for all the traits except for days to 75 per cent maturity however, when compared with checks, genotypes showed significant variation for all the traits under study except days to 50 per cent flowering.

Estimates of parameters of variability

Mean performance and range

Estimates of mean values for 240 mutant lines belonging to different treatments (Table 3) along with three checks were recorded. A wide range of genetic variability was observed for all the characters under study indicating the generation of variability through mutagenesis.

Days to 50 per cent flowering varied from 82.34 (T5-P2) - 107.01 (T4-P2) days with an average of 94.45 days. The mean values of mutant lines for number of days to 75 per cent maturity varied from 148.48 - 176.51 days with a mean of 165.81 days. Seven mutant lines were earlier in maturity as compared to the best check 'GPF-2' (160.98 days).The mean values of mutant lines for plant height varied from 14.30 - 42.77 cm with an average of 30.54 cm. Primary branches per plant ranged from 1.81 - 3.81 with a mean value of 2.63. The number of pods per plant ranged from 6.66 - 31.69 with a grand mean of 19.15 and the number of seeds per pod had a range of 1.15 - 2.05 with an average of 1.57. Range of 20.77 - 60.04 g with a grand mean of 34.48 g was observed in biological yield per plant. Seed yield per plant ranged from 7.65 - 22.05 g with an average of 11.22 g. The mutant lines obtained had an average 100 seed weight of 37.94 g, ranging from 33.18 - 46.48 g. The mean values of genotypes for harvest index varied from 13.59 - 69.32 per cent with a grand mean of 33.74 per cent.

Coefficients of variation

Mutatagenesis is a potent method of generating variability and its use in chickpea breeding is not new (Singh *et al*. 2018, Kumar *et al*. 2019, Sharma *et al*. 2019, Gazal *et al*. 2020 and Sharma *et al*. 2020). The PCV and GCV values are the indicators of observed phenotypic and genotypic variability, respectively. PCV values were higher than their corresponding GCV values for all the traits studied which indicated that the apparent variation is not only due to the genotypes but also due to the influence of the environment (Table 3).

None of the traits had high PCV and GCV estimates however, moderate PCV and GCV estimates however, moderate PCV and GCV per cent was observed in primary branches per plant, pods per plant, seed per pod, seed yield per plant and harvest index. Days to 50 per cent flowering, days to 75 per cent maturity and 100 seed weight had low PCV and GCV per cent whereas, estimates of plant height for PCV was high while, GCV was low.

Similar results were found by Kumar *et al*. (2014) and Manikanteswara *et al*. (2018) for seed yield per plant and harvest index. Balasaheb *et al*. (2018) and Chandra *et al*. (2015) found similar results for the biological yield number of pods per plant. Jakhar *et al*. (2016) also reported similar results for branches per

Table 3. Mean, range and variability parameters in chickpea

Traits	Mean	Range	PCV (%)	GCV (%)	h^2_{bs} (%)	GA (% of mean)
Days to 50 per cent flowering	94.45	82.34 - 107.01	5.52	4.92	79.59	9.05
Days to 75 per cent maturity	165.81	143.48 - 176.51	2.56	1.57	37.76	1.99
Plant height (cm)	30.54	14.30 - 42.77	10.96	9.59	76.65	17.30
Primary branches per plant	2.63	1.81 - 3.81	14.41	12.50	75.34	22.36
Pods per plant	19.15	12.63 - 31.69	16.31	15.02	84.74	28.48
Seeds per pod	1.57	1.15 - 2.05	15.29	14.94	95.57	30.09
Biological yield per plant (g)	34.48	20.77 - 60.04	20.15	19.39	92.51	38.41
Seed yield per plant (g)	11.22	7.13 - 22.05	19.50	18.90	94.02	37.76
100 Seed weight	37.94	20.30 - 46.48	5.08	3.01	91.41	46.13
Harvest index (per cent)	33.74	13.59 - 69.32	24.50	23.42	35.14	3.68

plant. Low PCV and GCV values were observed for days to 50 per cent flowering, days to 75 per cent maturity and 100 seed weight. Usefi *et al.* (2017) and Balasaheb *et al*. (2018) also reported similar findings for days to 50 per cent flowering and days to 75 per cent maturity.

Heritability in broad sense (h^2_{bs}) and genetic advance

The present study revealed that heritability in broad sense was high (>70 per cent) for days to 50 per cent flowering, plant height, primary branches per plant, pods per plant, seeds per pod, biological yield per plant, seed yield per plant and 100-seed weight (Table 3) thereby indicating the ability of plants to transmit the genes to their off-springs for these characters. High heritability for these traits revealed the lesser influence of the environment and the greater role of a genetic component of variation. Thus, the selection for these traits on the basis of phenotypic expression would be more effective and can be relied upon.

The estimates of heritability alone fail to indicate the response to selection. The heritability estimates appear to be more meaningful when accompanied by estimates of genetic advance than alone (Johnson *et al*. 1955). Thus, the genetic advance has an added edge over heritability as a guiding factor to breeders in various selection programmes.

High genetic advance (>30 per cent) coupled with high heritability (>70 per cent) estimates were observed for biological yield per plant, seeds per pod, 100 seed weight and seed yield per plant (Table 3) indicating the predominance of additive gene action in the inheritance of these characters. Balasaheb *et al*. (2018) and Kumari *et al*. (2013) found similar findings for biological yield per plant and seed yield per plant. Jakhar *et al*. (2016) found similar results for seeds per pod. Vaghela *et al*. (2010) and Sharanappa *et al*. (2014) found similar findings for seed yield per plant and biological yield per plant.

High heritability (>70 per cent) with moderate genetic advance (20-30 per cent) was observed for primary branches per plant and pods per plant. Kumari *et al*. (2013) and Vaghela *et al*. (2010) found similar findings for pods per plant. Balasaheb *et al*. (2018) found similar results for pods per plant and branches per plant. Sharanappa *et al*. (2014) found the same findings for branches per plant.

High heritability (>70 per cent) coupled with low genetic advance (<20 per cent) was observed for days to 50 per cent flowering and plant height which suggested that these traits has a lesser amount of additive genetic variance and that the rate of progress through selection is likely to be low. Balasaheb *et al*. (2018) found similar results for days to 50 per cent flowering. Thakur *et al*. (2018) found similar findings for plant height. Dhar *et al.* (2012) and Chopdar e*t al.* (2017) found the same results for days to 50 per cent flowering and plant height.

Correlation coefficient analysis

After understanding the nature of variation present in traits under study, it would be desirable to know the nature and magnitude of associations among these characters in order to bring out improvement in one character with low heritability through other trait having apositive association with it along with high heritability. Higher the correlation between independent and dependent variable, greater is the selection efficiency for the dependent trait.

In the present investigation, seed yield per plant showed positive and significant correlations with pods per plant, seeds per plant, harvest index and 100 seed weight (Table 4) which except harvest index, also had high heritability coupled with high genetic advance (Table 2). Therefore, indirect selection for high yield through these traits would give better results.

Besides, seed yield per plant showed negative and significant correlation with days to 75 per cent maturity. This kind of association indicates that early maturing genotypes had low yield potential. Correlation coefficient between other traits revealed that 100 seed weight, harvest index, pods per plant and primary branches per plant had positive association among themselves (Table 4). Tadesse *et al*. (2016) also reported a positive association of chickpea seed yield with days to flowering, days to maturity, number of pods per plant, number of seeds per pod, stand count at harvest, plant height and biomass.

Similarly, biological yield, plant height, branches per plant and pods per plant had significant and positive associations among themselves. In addition, pods per plant had a significant and positive association with branches per plant and branches per plant with plant height. Similar positive correlations have been reported in different studies with variable

Table 4. Estimation of correlation coefficients among various traits in chickpea

	Days to 75% maturity	Plant height	Primary branches per plant	Pods per plant	Seeds per pod	Biological yield per plant	Harvest index	100-seed weight	Seed yield per plant
Days to 50 per cent flowering	-0.025	0.007	-0.145*	0.03	0.038	-0.064	-0.012	0.071	0.037
Days to 75 per cent maturity		-0.159*	-0.034	-0.076	0.062	-0.019	0.05	0.009	-0.004*
Plant height			0.276*	0.065	-0.073	0.290*	-0.115	-0.250*	-0.062
Primary branches per plant				0.156*	-0.032	0.538*	-0.083	-0.337*	0.118
Pods per plant					-0.427*	0.171*	-0.008	0.190*	0.439*
Seeds per pod						-0.121	0.03	0.407*	0.415*
Biological yield per plant							-0.01	-0.662*	0.102
Harvest index								0.211*	0.262*
100-seed weight									0.647*

* Significant at $p \leq 0.05$

genotypes by Santosh *et al*. (2017) and Chandra *et al*. (2015) for plant height and pods per plant, Chopdar *et al*. (2017), Jha *et al*. (2012) and Dhar *et al*. (2012) for biological yield and branches per plant .

A negative association of days to 50 percent flowering with biological yield per plant, days to 75 per cent maturity, harvest index and primary branches; days to 75 per cent maturity with branches per plant, pods per plant and biological yield per plant; plant height and primary branches per plant with seeds per pod, harvest index and 100 seed weight.

Aarif *et al*. (2014) and Santosh *et al*. (2017) reported a negative correlation of days to 50 per cent flowering with days to 75 per cent maturity, harvest index and primary branches per plant, while a correlation of the same was noticed with biological yield per plant by Kumar *et al*. (2014).

Other researchers (Nitesh *et al*. 2018) also observed similar results. A negative correlation of days to 75 per cent maturity with primary branches per plant, biological yield and pods per plant have been reported by Shafique *et al.* (2016) and Ali *et al*. (2011). Kanouni *et al*. (2016) also reported a negative correlation of 100 seeds weight with plant height, seeds per pods and primary branches per plant were obtained and a negative correlation of 100-seed weight with harvest index was also observed by Chandra *et al*. (2015) and Jeena *et al*. (2005).

Conclusion

Induced mutagenesis has been used for ages for generating variability. The nature of variation generated through non-directed mutagenesis cannot be predicted however, extensive screening of the material generated has often led to the selection of genotypes with one or few desirable traits which can be directly or indirectly used in varietal development. The genotypes obtained from this study can be effectively used to develop varieties with high yield.

Conflict of interest: The authors have no conflict of interest in this research paper.

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