

## Induced polygenic variability for quantitative traits in chickpea var. Pusa-372

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### Abstract

Induction and evaluation of polygenic variability following treatments with gamma rays, EMS and their combinations were studied in chickpea var. Pusa-372. Mean values for various quantitative traits increased at lower or intermediate treatments and decreased at higher treatments in  $M_2$  generation. For days to flowering, days to maturity and plant height, mean values significantly decreased, whereas, for yield and yield contributing traits, mean values increased significantly in  $M_3$  generation. A considerable amount of variability was induced in the treated populations in  $M_2$  generation. Heritability and genetic advance values were quite high in  $M_2$  as compared to control for all polygenic traits which increased further in  $M_3$  for all yield contributing traits. Increase in the mean values of various polygenic traits, especially yield contributing traits, coupled with increase in heritability and genetic advance suggest fixation of desirable alleles for these traits and scope for selection of desirable high yielding types in chickpea.

**Key words:** Gamma rays, EMS, genetic variability, polygenic traits, *Cicer arietinum*.

### Variabilidade poligênica induzida para características quantitativas em grão de bico var. Pusa-372

### Resumo

Indução e avaliação da variabilidade poligênica seguindo tratamentos com raios gama, EMS e suas combinações foram estudadas em grão de bico var. Pusa-372. Os valores médios para várias características quantitativas aumentaram a tratamentos mais baixos ou intermediários e diminuíram a tratamentos mais elevados na geração  $M_2$ . Para dias para florescimento, dias para maturação e altura da planta, os valores médios diminuíram significativamente, enquanto que, para a produção e as características que contribuem para seu rendimento, os valores médios aumentaram de forma significativa na geração  $M_3$ . Uma quantidade considerável de variabilidade foi induzida em populações tratadas na geração  $M_2$ . Os valores de herdabilidade e avanço genético foram bastante elevados em  $M_2$  se comparados ao grupo controle de todos os traços poligênicos, que aumentaram ainda mais no  $M_3$  para todas as características de rendimento de contribuição. O aumento nos valores médios de vários traços poligênicos, especialmente traços que contribuem para o rendimento, juntamente com o aumento da herdabilidade e o avanço genético, sugerem fixação de alelos desejáveis para essas características e possibilidades de seleção de tipos de alto rendimento desejável para o grão de bico.

**Palavras-chave:** raios Gamma, EMS, variabilidade genética, traços poligênicos, grão de bico, *Cicer arietinum*

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## Introduction

Grain legumes include a wide variety of crops belonging to the family leguminosae. All of them are valued for protein rich grains and through symbiotic association with microbes, and day are able to fix atmospheric nitrogen and improve the physical and chemical properties of the soil. Chickpea (*Cicer arietinum* L.) is one of the most dominant pulse crops of India. The genetic variation in chickpea is limited probably due to its monophyletic descendance from *Cicer reticulatum* (Abbo et al., 2003; Ladizinsky & Alder, 1976). Due to lack of sufficient variability for yield and its component traits in chickpea, conventional methods of breeding have limited scope for its improvement. Induction of mutations using physical and chemical mutagens is one of the important ways to generate new variability and the potential of this technique is understood by the fact that more than 2250 varieties have been derived through induced mutations and the economic impact of these mutant cultivars has been realised (Ahloowalia et al., 2004; Maluszynski et al., 2000). In grain legumes alone, more than 264 legume cultivars have been developed through induced mutations (Bhatia et al., 2001). In the past several years, extensive studies have been undertaken on mutagenesis for the induction of genetic variability and improvement of economic traits in several crop plants (Larik et al., 2009; Sharma et al., 2005; Sakin & Yildirim, 2004; Khan et al., 2004; Singh et al., 1998; Mike, 1988; Sharma, 1986). Information on the quantum of induced polygenic variability or micromutations and the genetic parameters for different polygenic traits in segregating generations of mutagenized populations gives an indication about the scope of improvement in these traits through selection (Sheeba et al., 2003). Estimates of genetic parameters like phenotypic and genotypic coefficient of variability (PCV, GCV), heritability ( $h^2$ ) and genetic advance (GA) for various quantitative traits are useful in designing an effective breeding programme. The observed variability is a combined estimate of genetic and environmental causes, of which only the former one is heritable.

The estimates of genotypic coefficient of variation and heritability of various quantitative traits are essential since they indicate the degree of stability to the environmental fluctuations and the potential transmissibility of a character from parent to offspring and from generation to generation. However, the estimates of heritability alone do not provide an idea about the expected gain in the next generation, but they have to be considered in conjunction with the estimates of genetic advance. Increased variability in the form of high heritability and genetic advance for different quantitative traits has been reported by many workers in different crop plants (Khan & Goyal, 2009; Muduli & Misra, 2008; Khan & Qureshi, 2006; Coimbra et al., 2004; Tickoo & Chandra,

1999; Sharma & Sharma, 1982).

In the present study, an attempt has been made to ascertain the magnitude of induced genetic variability through the use of gamma rays and EMS in  $M_2$  and  $M_3$  generations for various quantitative traits in chickpea var. Pusa-372.

## Materials and Methods

The seed material for the present study was procured from the Genetics Division, IARI, New Delhi India. Dry and healthy seeds of chickpea var. Pusa-372 were treated with different doses of gamma rays (150, 200, 300 and 300 Gy) and various concentrations of EMS (0.1, 0.2, 0.3 and 0.4%) prepared in phosphate buffer (pH=7) for 6h with intermittent shaking at intervals. A portion of irradiated seeds was also subjected to combination treatments with EMS (200Gy+0.2%, 300Gy+0.2%, 200Gy+0.3% and 300Gy+0.3% EMS) for 6h. For EMS treatments, seeds were pre-soaked in distilled water for 12 h and the treated seeds were washed thoroughly in running tap water to remove any residual effect of the mutagen. Each treatment including control comprised of 300 seeds. Thereafter the treated and control seeds were sown in the field in three replicates in a complete randomized block design with seed to seed and row to row distance maintained at 20cm and 30cm respectively. Seeds harvested from individual  $M_1$  plants in each dose/treatment were sown as  $M_2$  families in three replicates in the field. Observations on various quantitative traits were recorded on 10-15 normal looking plants of each progeny from treated as well as control populations. The progenies segregating for macro mutations were not used for such analysis. Based on mutagenic effectiveness and efficiency recorded in  $M_1$  and  $M_2$  (Wani, 2009) and the performance of yield and other desirable traits, the following treatments were selected in  $M_2$  for raising  $M_3$  generation viz. Gamma rays (200Gy & 300Gy); EMS (0.2% & 0.3%) and combination treatments (200Gy+0.2%EMS & 300Gy+0.2% EMS). In each of these selected treatments, for raising  $M_3$  generation, such 10-15  $M_2$  progenies were selected which showed significant deviation in mean values in the desired direction particularly for the yield and yield contributing traits from the mean values of control. Seeds from each selected progeny in  $M_2$  were bulked by taking an equal amount of seeds from all  $M_2$  plants of a single progeny. A random sample of this bulk was then sown in the field to raise  $M_3$  generation.

Data on various quantitative traits viz., days to flowering, days to maturity, plant height, number of fertile branches per plant, number of pods per plant, number of seeds per pod, 100 seed weight and total seed yield per plant were subjected to statistical analysis (Singh & Chaudhary, 1985) to assess the extent of induced variation in  $M_2$  and  $M_3$  generations. From analysis of variance (ANOVA), the components of coefficient of variation viz. phenotypic

and genotypic coefficient of variation (PCV & GCV) and heritability in broad sense ( $h^2$ ) were computed as per standard statistical procedures. The expected genetic advance (GA) as percentage of mean was computed using the formula suggested by Allard (1999). The significant differences (LSD) between treated and control population means were computed by the method given by Snedecor & Cochran (1967) with some suitable modifications.

For convenience, 100Gy gamma rays, 0.1% EMS, 200Gy+0.2%EMS and 300Gy+0.3%EMS are named as lower treatments. Similarly 300Gy, 400Gy, 0.2%EMS, 0.3%EMS are named as intermediate treatments, whereas, 400Gy, 0.4%EMS, 200Gy+0.3%EMS and 300Gy+0.3% EMS are named as higher treatments in the literature.

### Results and Discussion

Perusal of results on various quantitative traits in  $M_2$  and  $M_3$  generations of chickpea var. Pusa-372 in Tables 1 and 2 indicate that mean shifted significantly ( $P \geq 0.01, 0.05$ ) in both positive and negative direction in  $M_2$  generation, negative shifts being observed at higher treatments of all mutagenic treatments while positive shifts were more pronounced at intermediate treatments of gamma rays and EMS and lower combination treatments for almost all quantitative traits except for days to flowering and maturity. Mean days to flowering and maturity significantly ( $P \geq 0.01, 0.05$ ) decreased in  $M_3$  generation in almost all selected treatments if compared to control with a few exceptions. In case of plant height, significant ( $P \geq 0.01, 0.05$ ) reduction in mean plant height were achieved in case of EMS treatments and the combination treatment 200Gy+0.2%EMS, where as significant ( $P \geq 0.01$ ) increase in plant height were achieved in 300Gy gamma rays and 300Gy+0.2%EMS treatments in  $M_3$  generation. In yield and yield contributing traits such as number of fertile branches per plant, number of pods per plant, number of seeds per pod, 100 seed weight and total yield per plant, mean values increased significantly ( $P \geq 0.01, 0.05$ ) from  $M_2$  to  $M_3$  generation in most of the selected treatments if compared to their respective controls. Shift in mean values in both positive and negative directions after mutagenic treatments has been reported by many works (Mensah & Obadoni, 2007; Khan & Qureshi, 2006; Waghmare & Mehra, 2000). Some articles have described negative shifts in mean values for polygenic traits following mutagenic treatments in  $M_2$  and  $M_3$  generations (Muduli & Misra, 2008), whereas, many others reported positive shifts in the mean values of polygenic traits in  $M_2$  and  $M_3$  generations (Khan & Wani, 2006; Khan et al., 2004). Negative shift in mean values has been attributed either to physiological damage caused chiefly by chemical mutagens or to chromosomal aberrations caused mainly by irradiations (Brock, 1971). Induction of mutations with negative effects could also be

the reason for decrease in mean values in some mutagenic treatments (Scossiroli et al., 1966; Singh et al., 2000). Contrary to this, increase in mean values following mutagenic treatments have been attributed to the induction of more positive mutations for such traits (Khan & Wani, 2006). Since quantitative traits have a complex genetic constitution involving large number of genes interacting with one another, consequently variations in both directions is expected. Present results indicate that induced mutations are random, polydirectional and quantitative in nature and cause heritable changes in polygenic systems. Significant decrease in mean values for days to flowering, days to maturity and plant height in most of the selected treatments in  $M_3$  generation coupled with high variability and heritability offer the possibility of selecting suitable mutants for these traits in chickpea. Similar results have been reported by other workers (Singh et al., 2000; Waghmare & Mehra, 2000). On the other hand, increase in mean values for yield and yield contributing traits from  $M_2$  to  $M_3$  generation as observed in the present study could be a result of direct selection for yield exercised in  $M_2$  generation (Khan & Qureshi, 2006; Khan et al., 2004; Waghmare & Mehra, 2000).

It is clearly evident in Table 1 and 2 that a considerable amount of variability was induced in  $M_2$  generation for all quantitative traits in the mutagenic populations if compared to control. Intermediate treatments of gamma rays and EMS and lower combination treatments were in general most effective in inducing maximum variability. Among different quantitative traits, the values of PCV and GCV were highest for number of fertile branches per plant followed by yield per plant, plant height and number of pods per plant. In case of days to flowering, days to maturity and plant height, the amount of variability, in general, decreased from  $M_2$  to  $M_3$  generation as it is evident by the decrease in the values of PCV and GCV in most of the selected treatments with a few exceptions. However, for all yield contributing traits, the amount of genetic variability increased further in some selected treatments while it decreased in other as for  $M_3$  generation. Increase in the estimates of PCV and GCV for various quantitative traits in the treated populations indicate better chances of selection to be successful and suggest that there is a good scope for yield improvement through effective selection in chickpea. These results are in agreement with other reports in different crop plants (Muduli & Misra, 2008; Mensah & Obadoni, 2007; Khan & Wani, 2006; Kumar & Dubey, 2001). The differences between PCV and GCV were quite high in case of most of the polygenic traits under study, indicating that such traits are highly influenced by environment. On the contrary, the differences were comparatively small for traits like number of seeds per pod and 100 seed weight, inferring low environmental influence on these

**Table 1.** Estimates of genetic parameters for various quantitative traits in M<sub>2</sub> generation of chickpea (*Cicer arietinum* L.) var. Pusa-372.

Treatment	Mean ±SE	Shift in mean	P C V (%)	G C V (%)	h <sup>2</sup>	G A (% of mean)	Mean ±SE	Shift in mean	P C V (%)	G C V (%)	h <sup>2</sup>	G A (% of mean)
<b>Days to Flowering</b>												
Control	87.46± 0.75	0.00	7.52	4.75	39.71	7.90	142.50± 0.84	0.00	5.12	3.23	39.67	5.36
<b>Days to Maturity</b>												
150 Gy	85.66± 0.85	-1.80	8.51	5.59	43.16	9.69	140.46± 1.03	-2.04	5.68	3.64	41.10	6.17
200Gy	87.23±1.06	-0.23	15.24	12.16	63.71	25.63	140.26±1.03	-2.24	7.46	5.68	57.91	11.40
300Gy	85.06±0.99	-2.40	9.98	7.33	53.97	14.21	136.33±0.93	-6.17	7.01	4.85	48.03	8.88
400Gy	91.53± 1.20	+4.07	8.95	7.31	66.69	15.76	142.80±1.00	+0.30	5.03	4.16	68.48	9.10
LSD 5% = 0.97, 1% = 1.42												
<b>EMS</b>												
0.1%	88.56±0.89	+1.10	7.57	5.50	52.74	10.54	142.86± 1.07	+0.36	5.74	4.19	53.40	8.09
0.2%	90.06±1.00	+2.60	13.46	10.75	63.85	22.68	140.36±1.29	-2.14	6.05	5.38	79.09	12.63
0.3%	90.83±1.03	+3.37	7.21	6.28	75.94	14.45	144.50±1.08	+2.00	6.61	4.79	52.61	9.18
0.4%	90.53±0.89	+3.07	13.62	9.36	47.30	17.01	144.73±0.98	+2.23	6.59	4.19	40.41	7.03
LSD 5% = 1.16, 1% = 1.69												
<b>y-rays+ EMS</b>												
200Gy+0.2%	89.76 ±0.89	+2.30	9.60	8.85	84.96	21.52	138.23±1.17	-4.27	7.32	6.34	75.20	14.52
300Gy+0.2%	89.20 ± 1.03	+1.74	12.70	10.22	64.72	21.71	144.60±1.29	+2.10	9.69	7.03	52.51	13.44
200Gy+0.3%	92.40 ± 1.10	+4.94	9.87	6.75	46.71	12.18	144.66± 1.22	+2.16	6.80	4.66	46.90	8.42
300Gy+0.3%	90.53 ± 0.90	+5.27	11.16	8.47	57.69	16.99	146.13±1.04	+3.63	5.03	3.97	62.39	8.28
LSD 5% = 1.99, 1% = 2.90												
<b>Plant Height (cm)</b>												
Control	55.73± 0.65	0.00	7.99	4.51	31.81	6.71	4.90 ± 0.88	0.00	20.79	12.48	36.03	19.78
<b>Number of Fertile Branches per Plant</b>												
150 Gy	55.07 ± 0.90	-0.66	11.23	6.89	37.69	11.17	5.16 ± 0.23	+0.26	24.68	14.07	32.50	21.17
200Gy	56.01 ± 0.80	+0.28	10.21	7.87	59.41	16.02	5.70 ± 0.29	+0.80	32.83	17.86	29.60	25.66
300Gy	56.43 ± 0.96	+0.70	15.63	10.57	45.67	18.85	5.83 ± 0.29	+0.93	40.04	26.28	43.08	45.54
400Gy	51.68 ± 0.85	-4.05	11.90	8.64	52.66	16.55	4.56 ± 0.29	-0.34	50.59	32.00	40.01	53.44
LSD 5% = 1.59, 1% = 2.31												
<b>EMS</b>												
0.1%	56.21 ± 0.66	+0.48	8.22	4.92	35.86	7.78	5.20 ± 0.23	+0.30	19.63	13.08	44.41	23.02
0.2%	55.25 ± 0.84	-0.48	11.20	8.48	57.25	16.94	6.03 ± 0.25	+1.13	47.16	27.86	34.89	43.44
0.3%	52.94 ± 1.04	-2.79	9.63	8.27	73.87	18.78	5.80 ± 0.32	+0.90	30.01	22.84	57.93	45.90
0.4%	47.50 ± 0.79	-8.23	12.99	8.20	39.82	13.66	4.06 ± 0.24	-0.84	34.84	24.81	50.71	46.65
LSD 5% = 0.49, 1% = 0.71												
<b>y-rays+ EMS</b>												
200Gy+0.2%	54.60 ± 1.02	-1.13	17.24	12.62	53.59	24.39	5.93 ± 0.27	+1.03	43.14	29.01	45.22	51.50
300Gy+0.2%	56.75 ± 0.99	+1.02	15.82	10.63	45.11	18.84	6.60 ± 0.29	+1.70	33.75	24.91	54.49	48.55
200Gy+0.3%	49.45 ± 0.86	-6.28	9.77	7.79	63.55	16.40	4.56 ± 0.29	-0.34	55.02	34.49	39.31	57.09
300Gy+0.3%	47.80 ± 1.03	-7.93	15.18	9.59	39.92	16.00	3.90 ± 0.24	-1.00	26.72	21.22	63.08	44.50
LSD 5% = 1.76, 1% = 2.56												
<b>Number of Pods per Plant</b>												
Control	152.73 ± 1.91	0.000	10.37	5.83	31.60	8.65	1.63 ± 0.020	0.00	4.02	2.45	37.21	3.95
<b>Number of Seeds per Plant</b>												
150 Gy	150.06 ± 2.57	-2.76	9.68	6.08	39.44	10.08	1.67 ± 0.026	+0.04	5.58	3.83	47.13	6.95
200Gy	158.46 ± 2.80	+5.73	9.23	7.64	68.50	16.69	1.80 ± 0.032	+0.17	4.48	3.64	66.15	7.82
300Gy	164.60 ± 2.74	+11.87	12.34	8.44	46.77	15.24	1.76 ± 0.029	+0.13	5.96	4.72	62.72	9.87
400Gy	143.36 ± 2.59	-9.37	19.02	11.13	34.25	17.20	1.50 ± 0.024	-0.13	11.35	7.97	49.31	14.78
LSD 5% = 3.91, 1% = 5.69												
<b>EMS</b>												
0.1%	154.40 ± 2.51	+1.67	10.00	6.62	43.81	11.57	1.66 ± 0.025	+0.03	9.21	6.73	53.42	12.99
0.2%	160.53 ± 3.03	+7.80	13.55	8.16	36.29	12.98	1.73 ± 0.033	+0.10	7.26	5.45	56.33	10.80
0.3%	156.76 ± 2.37	+4.03	13.59	10.34	57.86	20.76	1.70 ± 0.033	+0.07	8.78	5.79	43.50	10.08
0.4%	141.60 ± 2.46	-11.13	13.93	9.82	49.63	18.26	1.46 ± 0.023	+0.17	10.14	7.69	57.50	15.39
LSD 5% = 3.58, 1% = 5.21												
<b>y-rays+ EMS</b>												
200Gy+0.2%	158.23± 2.87	+5.50	17.02	9.29	29.80	13.38	1.75 ± 0.035	+0.12	7.32	4.85	43.90	8.48
300Gy+0.2%	161.76 ± 2.94	+9.03	10.16	7.31	51.80	13.90	1.70 ± 0.028	+0.07	6.98	5.29	57.44	10.59
200Gy+0.3%	143.73 ± 2.64	-9.00	11.84	9.44	63.54	19.86	1.47 ± 0.024	-0.16	7.93	6.34	63.97	13.40
300Gy+0.3%	138.26 ± 2.44	-14.47	12.16	8.74	51.69	16.60	1.38 ± 0.025	-0.25	8.99	6.15	46.75	11.09
LSD 5% = 4.38, 1% = 6.95												
<b>100 Seed Weight (g)</b>												
Control	13.50 ± 0.10	0.00	4.18	2.38	32.40	3.57	31.80 ± 0.45	0.00	10.99	4.61	17.61	5.11
<b>Total Yield per Plant (g)</b>												
150 Gy	12.80 ± 0.14	-0.70	4.47	2.81	39.56	4.67	32.24± 0.47	+0.44	7.80	4.96	40.51	8.34
200Gy	13.63 ± 0.17	+0.13	7.23	4.76	43.39	8.28	34.50 ± 0.64	+2.70	21.73	9.62	19.59	11.24
300Gy	14.22 ± 0.18	+0.72	9.57	5.19	29.46	7.44	35.54 ± 0.67	+3.74	14.22	10.05	49.94	18.74
400Gy	13.75 ± 0.20	+0.25	5.05	3.96	61.54	8.21	28.73 ± 0.59	-3.07	20.36	9.42	21.40	11.50
LSD 5% = 0.16, 1% = 0.23												
<b>EMS</b>												
0.1%	13.56 ± 0.16	+0.06	9.10	5.52	36.84	8.85	32.07 ± 0.48	+0.27	8.76	5.49	39.24	9.08
0.2%	14.98 ± 0.20	+1.48	5.49	3.96	52.03	7.54	35.78 ± 0.69	+3.98	22.92	11.31	24.34	14.73
0.3%	15.56 ± 0.19	+2.06	7.49	6.23	69.25	13.69	34.13 ± 0.65	+2.33	13.66	9.35	46.89	16.91
0.4%	12.73 ± 0.19	-0.77	5.33	3.69	47.98	6.75	28.10 ± 0.67	-3.70	22.14	12.65	32.67	19.09
LSD 5% = 0.25, 1% = 0.37												
<b>y-rays+ EMS</b>												
200Gy+0.2%	14.04 ± 0.16	+0.54	10.40	6.88	43.72	12.00	34.37 ± 0.65	+2.57	14.74	7.61	26.63	10.36
300Gy+0.2%	14.90 ± 0.20	+1.40	5.71	4.38	58.85	8.87	32.15 ± 0.64	+0.35	21.45	13.51	39.65	22.45
200Gy+0.3%	13.25 ± 0.20	-0.25	5.81	3.49	36.14	5.54	27.62 ± 0.06	-4.18	12.49	8.53	46.57	15.36
300Gy+0.3%	13.40 ± 0.18	-0.10	6.15	4.49	53.36	8.66	25.50 ± 0.56	-6.30	19.29	10.33	28.71	14.62
LSD 5% = 0.31, 1% = 0.46												

PCV= Phenotypic coefficient of variability, GCV = Genotypic coefficient of variability, GA = Genetic advance as percent of mean, h<sup>2</sup>= Heritability in broad sense

**Table 2.** Estimates of genetic parameters per various quantitative traits in M<sub>3</sub> generation of chickpea (*Cicer arietinum* L.) var. Pusa-372.

Treatment	Mean ± SE	Shift in mean	P C V (%)	G C V (%)	h <sup>2</sup>	GA (% of mean)	Mean ± SE	Shift in mean	P C V (%)	G C V (%)	h <sup>2</sup>	GA (% of mean)
<b>Days to Flowering</b>												
Control	87.16 ± 0.67	0.00	6.22	4.12	43.89	7.20	140.93± 0.80	0.00	4.32	2.92	45.61	5.21
200 Gy	85.43 ± 1.01	-1.73	13.80	10.72	60.38	22.00	137.40±0.89	-3.53	5.53	5.12	85.98	12.55
300 Gy	85.20 ± 0.89	-1.96	7.71	6.22	65.05	13.24	134.36±0.87	-6.57	7.05	5.50	60.81	11.32
LSD												
5% = 1.25, 1% = 2.08												
<b>EMS</b>												
0.2%	83.50 ± 1.02	-3.66	9.23	8.82	91.40	22.27	134.53±0.91	-6.40	4.13	3.84	86.63	9.44
0.3%	87.63 ± 0.80	+0.47	8.69	7.38	72.14	16.54	142.23±0.96	+1.30	5.73	4.29	56.19	8.49
LSD												
5% = 1.37, 1% = 2.28												
<b>γ-rays+ EMS</b>												
200Gy+0.2%	87.90 ± 0.86	+0.74	9.49	8.55	81.15	20.24	138.46 ± 0.97	-2.47	6.38	5.39	71.46	12.04
300Gy+0.2%	85.53 ± 0.89	-1.63	9.72	7.49	59.39	15.24	136.80±0.85	-4.13	5.76	4.79	69.20	10.53
LSD												
5% = 1.36, 1% = 2.26												
<b>Plant Height (cm)</b>												
Control	56.60 ± 0.63	0.00	6.47	4.13	40.70	6.95	5.13 ± 0.17	0.00	15.59	9.80	39.47	16.24
200 Gy	56.83 ± 0.67	+0.23	7.38	6.37	74.64	14.54	5.96 ± 0.25	+0.83	26.07	21.70	69.36	47.73
300 Gy	58.26 ± 0.79	+1.66	9.66	7.26	56.58	14.42	6.70 ± 0.30	+1.57	38.79	26.75	47.54	48.69
LSD												
5% = 1.28, 1% = 2.13												
<b>EMS</b>												
0.2%	54.53 ± 0.73	-2.07	7.58	6.28	68.54	13.72	8.50 ± 0.33	+3.37	25.62	19.58	58.40	39.50
0.3%	54.75 ± 0.75	-1.85	8.36	7.62	83.22	18.36	6.96 ± 0.32	+1.83	39.41	27.08	47.19	49.10
LSD												
5% = 1.18, 1% = 1.96												
<b>γ-rays+ EMS</b>												
200Gy+0.2%	53.50 ± 0.85	-3.10	9.38	7.94	71.64	17.74	7.03 ± 0.31	+1.90	37.13	26.67	51.58	50.56
300Gy+0.2%	58.72 ± 0.79	+2.12	10.79	8.47	61.51	17.53	7.40 ± 0.31	+2.27	26.20	21.57	67.76	46.88
LSD												
5% = 0.89, 1% = 1.48												
<b>Number of Pods per Plant</b>												
Control	152.80 ± 1.84	0.00	8.90	5.61	39.75	9.34	1.62 ± 0.02	0.00	3.49	2.62	56.25	5.18
200 Gy	164.73 ± 2.87	+11.93	10.08	7.58	56.55	15.05	1.78 ± 0.02	+0.16	5.84	5.21	79.63	12.27
300 Gy	165.50 ± 2.40	+12.70	10.21	8.76	73.57	19.83	1.75 ± 0.02	+0.13	6.71	6.23	86.23	15.28
LSD												
5% = 5.00, 1% = 8.30												
<b>EMS</b>												
0.2%	166.83 ± 3.35	+14.03	10.68	8.58	64.79	18.24	1.80 ± 0.02	+0.18	10.70	9.41	77.36	21.85
0.3%	162.36 ± 3.11	+9.56	11.66	9.22	62.55	19.25	1.75 ± 0.02	+0.13	9.91	8.36	71.09	18.60
LSD												
5% = 3.33, 1% = 5.52												
<b>γ-rays+ EMS</b>												
200Gy+0.2%	163.40 ± 2.59	+10.60	13.57	10.39	56.43	20.22	1.81 ± 0.02	+0.19	6.54	5.61	73.57	12.69
300Gy+0.2%	163.96 ± 2.75	+11.16	10.98	9.56	75.70	21.95	1.72 ± 0.02	+0.10	8.89	7.51	71.36	16.75
LSD												
5% = 0.47, 1% = 0.78												
<b>100 Seed Weight (g)</b>												
Control	13.73 ± 0.07	0.00	3.88	2.77	51.23	5.24	32.06±0.43	0.00	8.31	4.85	34.14	7.49
200 Gy	14.06 ± 0.10	+0.33	6.29	4.98	62.64	10.41	35.54 ± 0.54	+3.48	10.33	7.83	57.42	15.66
300 Gy	14.50 ± 0.10	+0.77	9.22	7.40	64.48	15.69	36.40 ± 0.60	+4.34	14.76	12.18	68.12	26.54
LSD												
5% = 0.13, 1% = 0.2												
<b>EMS</b>												
0.2%	15.42 ± 0.12	+1.69	7.05	6.24	78.14	14.55	37.36 ± 0.59	+5.30	19.09	14.20	55.29	27.87
0.3%	15.65 ± 0.11	+1.92	10.66	8.24	67.22	18.91	35.78 ± 0.56	+3.72	18.15	12.73	49.25	23.59
LSD												
5% = 0.13, 1% = 0.21												
<b>γ-rays+ EMS</b>												
200Gy+0.2%	14.52 ± 0.11	+0.79	6.56	5.72	75.86	13.14	35.21 ± 0.70	+3.15	22.94	15.78	47.35	28.67
300Gy+0.2%	15.74 ± 0.11	+2.01	7.35	6.84	86.54	16.80	35.06 ± 0.59	+3.00	12.05	9.55	62.78	19.97
LSD												
5% = 0.14, 1% = 0.24												
<b>Total Yield per Plant (g)</b>												
Control	13.73 ± 0.07	0.00	3.88	2.77	51.23	5.24	32.06±0.43	0.00	8.31	4.85	34.14	7.49
200 Gy	14.06 ± 0.10	+0.33	6.29	4.98	62.64	10.41	35.54 ± 0.54	+3.48	10.33	7.83	57.42	15.66
300 Gy	14.50 ± 0.10	+0.77	9.22	7.40	64.48	15.69	36.40 ± 0.60	+4.34	14.76	12.18	68.12	26.54
LSD												
5% = 1.90, 1% = 3.15												
<b>EMS</b>												
0.2%	15.42 ± 0.12	+1.69	7.05	6.24	78.14	14.55	37.36 ± 0.59	+5.30	19.09	14.20	55.29	27.87
0.3%	15.65 ± 0.11	+1.92	10.66	8.24	67.22	18.91	35.78 ± 0.56	+3.72	18.15	12.73	49.25	23.59
LSD												
5% = 1.91, 3% = 3.16												
<b>γ-rays+ EMS</b>												
200Gy+0.2%	14.52 ± 0.11	+0.79	6.56	5.72	75.86	13.14	35.21 ± 0.70	+3.15	22.94	15.78	47.35	28.67
300Gy+0.2%	15.74 ± 0.11	+2.01	7.35	6.84	86.54	16.80	35.06 ± 0.59	+3.00	12.05	9.55	62.78	19.97
LSD												
5% = 1.34, 1% = 2.22												

PCV= Phenotypic coefficient of variability, GCV = Genotypic coefficient of variability, GA = Genetic advance as percent of mean, h<sup>2</sup>= Heritability in broad sense

traits (Larik et al., 2009; Kumar & Dubey, 2001). Response to selection for quantitative traits is directly proportional to the function of its genetic variance, heritability and genetic (Khan et al., 2004; Kharkwal, 2003). The GCV measures the range of genetic variability shown by the plant trait; however, the GCV alone can not determine the amount of variation that is heritable. On the other hand, according to Johnson et al. (1955), heritability estimates along with genetic advance are usually more helpful than the heritability value alone in predicting the resultant effects of selection. Genetic advance is indicative of the expected genetic progress for a particular trait under selection procedure (Kaul & Garg, 1982) and consequently carries much significance in self pollinated crops. In the present investigation, heritability in broad sense and genetic advance were quite high in the treated populations if compared to control in M<sub>2</sub> generation. Heritability

increased further in all selected treatments from M<sub>2</sub> to M<sub>3</sub> generation for all quantitative traits with a few exceptions. Increase in heritability for all polygenic traits in M<sub>3</sub> if compared to M<sub>2</sub> could be due to an increased homozygosity of the genes involved. Similarly genetic advance decreased from M<sub>2</sub> to M<sub>3</sub> generation in case of days to flowering days to maturity and plant height in most of the selected treatments indicating that these traits are under the control of non-additive gene action (dominance and epistasis). However, for yield and its components, increase in heritability was associated with an increase in genetic advance from M<sub>2</sub> to M<sub>3</sub> in most of the selected treatments with a few exceptions, indicating predominance of additive genetic effects. These results are in agreement with earlier reports on various quantitative traits in different crop plants (Khan & Qureshi, 2006; Mensah et al., 2005; Sheeba et al., 2003). Since significant

gains in mean coupled with high heritability and genetic advance were achieved for yield and yield contributing traits in  $M_3$  generation, there is an indication that selection applied in  $M_2$  generation was effective. On the other hand, increase in genetic variability continued in some selected treatments in  $M_3$  for these traits indicating further chances of selection for desirable types in the advanced generations of treated populations. The efficiency of early generation ( $M_2$ ) selection has been reported earlier in lentil (Solanki & Sharma, 2002), fieldpea (Singh, 1988) and Mungbean (Tickoo & Chandra, 1999). According to Sneep (1977), selection for quantitative traits, such as yield, should preferably be carried out in early generations, because, most of the desired combinations of favourable alleles are likely to be lost in advanced generations due to intensive or even no selection for other traits. The present results on induced genetic variability in chickpea are encouraging, since some promising high yielding genotypes are expected to be isolated in future generations.

### Conclusions

Induced mutations have a great potential of enhancing genetic variability and thus improving yield potential in chickpea through effective handling of the mutagenized populations. The intermediate doses of gamma rays and lower combination treatments used in the present investigation are recommended for improvement of chickpea through mutation breeding.

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