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Induced Variability and Genetic Parameters for Agromorphological and Quality Traits in Soybean (*Glycine max* L.)

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Abstract A study was conducted with all genetic parameters in both mutagenic generations (M_3 and M_4) for all the traits have been recorded shift positive over the control (untreated population). In case of seed yield, highest PCV, GCV, heritability and genetic advance have been recorded in 0.15% dose of EMS treatment. Increase in coefficient of variation of the treated populations and high heritability with highest genetic advance for most of the agromorphological and quality traits over their corresponding controls offer a definite possibility of improving these traits by further selection in the succeeding generations. Mutagen doses specifically 20 kR, 40 kR, 20 kR+0.10% EMS and 20 kR+0.15% EMS could be considered as responsive for the improvement of various yield components and quality traits in soybean.

Keywords Soybean, Gamma rays, EMS, Genetic parameters, Quality traits.

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Introduction

Soybean (*Glycine max* L.) is the fourth important edible oil crop in India after groundnut, rapeseed-mustard and sunflower. In soybean, creation of genetic variability is very typical work due to its small flower size and self pollinated nature of flower. Emasculation and pollination operation are not successful under favorable condition and self-pollinated nature reduces the chances of success of hybridization program reported by Kavithamani et al. [1]. Therefore the most popular method for creating genetic variability is induced mutagenesis through physical mutagen (Gamma rays), chemical mutagen (Ethyle Methane Sulphonate) and their combined treatments. There are many useful genetic changes developed through mutation breeding including high yield, flower color, disease resistance and early maturity. The induced variability can be exploited to develop new genotypes of soybean with improved various yield component and quality traits. Induced mutation has been employed successfully for the improvement of various agromorphological and quality traits in soybean and other crops earlier [2, 3]. However, yield and its component traits are polygenic in nature therefore, only heritable portion of variability induced by mutation is meaningful for developing new improved varieties. Therefore, high heritability along with high genetic advance is more useful to assess the heritable portion of total variation. The main objective of the present research was to assess the nature and magnitude of induced genetic variability, heritability and genetic advance in M_3 and M_4 generations compared to check population for various agromorphological and quality traits in soybean.

Materials and Methods

A study was conducted at the N. E. Borlaug Crop Research Center of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The experimental material was consisted of one soybean variety i.e. PK 1029. 1000 dry seeds with moisture content of 10–12% of the cultivar PK 1029 of soybean were treated with three different doses (20kR, 30kR and 40 kR) of gamma rays at Bhaba Atomic Research Center, Tromby in Mumbai, with ^{60}CO gamma rays and three different doses, chemical treatment (0.05%, 0.10% and 0.15% of EMS) of Ethyl Methane Sulphonate ($CH_3SO_2C_2H_5$) of Sigma Ltd. USA was used at G. B. Pant University of Agricultural and Technology Pantnagar. The treated seeds along with control (untreated seeds) were sown for each genotype with plot size of row to row spacing 60 cm and seed to seed 10 cm. The experimental material was comprised of 11 treatments along with two controls (Dry seeds PK 1029 and Pre-soaked seed PK 1029). The individual seed of M_1 plant progenies were sown to raise M_2 progeny and seeds from 500 M_3 plants were harvested individually in each treatment and M_4 progeny raised in separate rows of 5.0 m length and plant to plant distance was 10—20 cm. in randomized complete block design with three replications in *kharif* season of 2012 and finally 50 seeds were sown in each row of 5 m length to raised M_4 generations. Uniform cultivation method and agricultural practices were followed for to raise M_1, M_2, M_3 and M_4 generations. Observations were recorded in M_3 and M_4 for 14 agromorphological and quality traits namely days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, dry matter weight per plant (g), number of pods per plant, number of seeds per pod, harvest index (g), 100 seed weight (g), oil contain (%), protein contain (%) and seed yield (g). Various parameters were estimated for each treatment in both M_3 and M_4 generations and compared with check for each trait separately. Both PCV and GCV were calculated as per the method suggested by Burton [4]. Heritability and genetic advance were calculated by the method suggested by Johnson et al. [5].

Results and Discussion

Induced variability, heritability (broad sense) and genetic advance in both M_3 and M_4 generations for 13 agromorphological and quality traits is presented in (Table 1). The knowledge of GCV, PCV and high heritability with high genetic advance for the traits is more important than the heritability alone because it will help us in deciding the scope for the improvement of that particular trait through selection by Johnson et al. [5]. All the genotypes showed variable response for different mutagenic treatments for all the traits, under study which showed that mutagenic treatments induced the variability to a great extent.

In M_3 generation, the treated population showed an increase in PCV (12.35), GCV (12.28), heritability (0.98) and genetic advance (25.19) in 40 kR dose of gamma rays over the check PK 1029 dry control but highest heritability (0.99) were noticed in 20 kR + 0.05% EMS, which is also higher than both the control. In M_4 generation, all the treated populations exhibited highest genetic advance (25.04) in 40 kR dose of gamma rays whereas highest PCV (12.09), GCV (12.00) and heritability (0.98) was recorded in 30 kR dose over the both checks (PK 1029 dry and PK 1029 presoaked). The highest increased in PCV, GCV, heritability and genetic advance for days to 50% flowering was recorded in 40 kR and 30 kR treatment in both M_3 and M_4 generation. Positive shift in all genetic parameters in both generations over the check is attributed to induction of higher proportion of positive mutation than negative mutation. It means these two treatments of gamma rays are more effective for induced variability in soybean for this trait. Similar findings were earlier reported [2, 3, 6—8]. In M_3 generation, the highest PCV (4.90) and GCV (4.80) in 20 kR+0.15% EMS, highest heritability (0.97) in 40 kR and highest genetic advance (9.22) was recorded in 0.05% treatment of EMS over PK 1029 dry check whereas in M_4 generation, highest PCV (4.90), GCV (4.86), genetic advance (9.92) was recorded in 20 kR+0.15% EMS and highest heritability (0.98) was recorded in 20 kR over check for days to maturity. The positive sift in all these genetic parameters for days to maturity were recorded in 20 kR+0.15% dose of EMS in both M_3 and M_4 generation. Similar finding were earlier reported [3, 7, 8].

Table 1. Genetic parameters for agromorphological and quality traits in M_3 and M_4 mutagenic generations of soybean.

Treatments	PCV		GCV		H (bs)		GA	
Days to 50% flowering								
Doses	M_3	M_4	M_3	M_4	M_3	M_4	M_3	M_4
20 kR	8.81	8.72	8.52	8.22	0.93	0.88	16.97	17.68
30 kR	10.14	12.09	10.04	12.00	0.98	0.98	20.51	20.41
40 kR	12.35	11.28	12.28	11.22	0.98	0.98	25.19	25.04
0.05% EMS	11.94	11.88	11.83	11.74	0.98	0.97	24.15	23.89
0.10% EMS	11.34	11.21	11.25	11.12	0.98	0.98	23.00	24.44
0.15% EMS	9.16	9.23	8.95	8.84	0.95	0.91	18.02	17.43
20 kR + 0.05% EMS	10.38	10.35	10.34	10.26	0.99	0.98	21.19	20.95
20 kR + 0.10% EMS	10.35	10.28	10.26	10.10	0.98	0.96	20.92	20.43
20 kR + 0.15% EMS	11.10	11.05	11.02	10.95	0.98	0.98	22.53	22.36
PK 1029 dry control	7.62	8.51	7.45	7.32	0.95	0.95	15.00	14.56
PK 1029 Presoaked	11.58	11.63	11.46	11.51	0.97	0.97	23.38	15.36
Days to maturity								
20 kR	3.79	3.01	3.20	2.98	0.71	0.98	5.58	6.10
30 kR	3.39	3.37	3.28	3.31	0.93	0.96	6.54	6.71
40 kR	3.98	3.99	3.94	3.95	0.97	0.97	8.04	8.06
0.05% EMS	4.58	4.40	4.52	4.35	0.97	0.97	9.22	8.86
0.10% EMS	3.18	4.19	3.13	4.14	0.97	0.98	8.40	8.46
0.15% EMS	3.37	3.50	3.15	3.44	0.87	0.96	6.05	6.97
20 kR + 0.05% EMS	4.13	4.17	4.09	4.12	0.97	0.97	8.33	8.39
20 kR + 0.10% EMS	4.10	4.05	3.99	3.96	0.94	0.95	7.99	7.99
20 kR + 0.15% EMS	4.90	4.90	4.84	4.86	0.97	0.98	8.99	9.92
PK 1029 dry control	2.84	2.81	2.79	2.80	0.96	0.96	5.65	5.67
PK 1029 Presoaked	3.72	3.72	3.68	3.69	0.97	0.97	7.50	7.52
Plant height								
20 kR	18.20	18.51	18.00	18.34	0.87	0.88	32.75	33.57
30 kR	18.13	17.47	18.10	17.43	0.89	0.89	31.43	32.02
40 kR	20.45	19.70	19.59	19.49	0.81	0.87	28.85	29.90
0.05% EMS	17.78	17.88	17.30	17.84	0.84	0.89	26.85	28.77
0.10% EMS	15.78	14.87	15.74	14.83	0.89	0.89	27.05	27.26
0.15% EMS	15.96	16.06	15.92	16.02	0.89	0.89	29.09	29.46
20 kR + 0.05% EMS	17.05	17.15	17.02	17.13	0.89	0.89	31.26	31.45
20 kR + 0.10% EMS	16.70	16.99	16.62	16.93	0.89	0.89	30.64	31.14
20 kR + 0.15% EMS	17.09	17.21	16.86	17.13	0.87	0.89	30.63	31.55
PK 1029 dry control	8.23	8.32	8.16	8.21	0.87	0.87	15.04	14.89
PK 1029 Presoaked	13.83	13.91	13.67	13.75	0.87	0.87	24.97	24.94
Seed yield per plant								
20 kR	17.24	16.94	15.98	16.57	0.87	0.85	31.80	29.67
30 kR	25.44	27.00	24.78	26.75	0.88	0.88	48.72	48.97
40 kR	32.34	29.65	31.32	29.24	0.88	0.87	44.54	53.16
0.05% EMS	30.25	29.21	28.78	29.09	0.87	0.89	50.45	53.56
0.10% EMS	30.55	28.01	29.13	27.55	0.86	0.86	47.22	49.65
0.15% EMS	28.21	27.27	27.45	27.00	0.89	0.88	53.92	49.43
20 kR + 0.05% EMS	30.24	28.61	29.32	28.28	0.86	0.87	47.72	51.31
20 kR + 0.10% EMS	20.52	19.50	19.54	19.17	0.87	0.86	46.79	39.42
20 kR + 0.15% EMS	30.23	29.24	29.22	29.00	0.88	0.88	49.55	53.03
PK 1029 dry control	6.98	7.36	5.45	6.37	0.72	0.74	14.30	13.03

Table 1. Continued.

Treatments	PCV		GCV		H (bs)		GA	
Doses	M_3	M_4	M_3	M_4	M_3	M_4	M_3	M_4
PK 1029 Presoaked	6.99	7.34	5.98	6.13	0.67	0.69	13.47	11.79
Number of primary branches per plant								
20 kR	13.67	14.68	6.17	10.36	0.20	0.49	5.66	14.93
30 kR	12.71	13.24	10.22	8.01	0.64	0.36	16.81	9.84
40 kR	15.62	14.33	5.46	9.16	0.12	0.40	3.90	11.98
0.05% EMS	15.01	15.01	11.69	9.04	0.60	0.36	18.64	11.13
0.10% EMS	14.90	15.65	7.17	10.28	0.23	0.43	7.06	13.76
0.15% EMS	15.01	11.72	7.91	11.62	0.27	0.48	8.54	16.61
20 kR + 0.05% EMS	13.63	15.03	9.26	12.14	0.46	0.65	12.84	20.16
20 kR + 0.10% EMS	15.07	14.33	3.96	5.12	0.69	0.12	6.79	3.73
20 kR + 0.15% EMS	17.77	18.14	10.91	12.66	0.44	0.48	16.33	18.08
PK 1029 dry control	11.55	12.59	3.60	8.98	0.45	0.50	2.35	13.20
PK 1029 Presoaked	13.87	13.07	8.38	6.82	0.36	0.27	11.28	7.23
Total dry matter per plant								
20 kR	21.50	21.50	21.33	21.37	0.78	0.78	33.28	34.55
30 kR	33.78	32.27	33.62	32.25	0.79	0.79	56.68	52.51
40 kR	34.64	35.12	34.46	34.94	0.79	0.78	56.37	56.45
0.05% EMS	32.90	33.11	32.79	32.99	0.79	0.79	55.44	53.88
0.10% EMS	33.63	32.76	32.57	32.70	0.79	0.79	52.11	53.31
0.15% EMS	31.42	30.47	31.40	30.45	0.79	0.79	50.12	49.61
20 kR + 0.05% EMS	36.49	36.72	36.47	36.71	0.79	0.79	59.40	59.76
20 kR + 0.10% EMS	26.87	26.91	26.82	26.89	0.78	0.79	46.26	49.40
20 kR + 0.15% EMS	35.36	34.62	35.34	34.59	0.78	0.79	60.44	56.51
PK 1029 dry control	12.36	12.40	12.32	12.37	0.79	0.79	42.87	30.49
PK 1029 Presoaked	14.84	14.90	14.81	14.88	0.79	0.79	36.08	35.69
Number of pods per plant								
20 kR	35.28	36.22	35.27	36.21	0.79	0.79	57.42	51.40
30 kR	32.31	31.04	32.30	31.03	0.79	0.79	52.59	47.54
40 kR	30.44	31.33	30.42	31.30	0.79	0.79	49.53	49.35
0.05% EMS	26.10	25.90	26.09	25.88	0.79	0.79	42.48	42.16
0.10% EMS	40.58	40.43	40.57	40.40	0.79	0.79	66.05	67.13
0.15% EMS	29.32	29.13	29.31	29.12	0.79	0.79	47.70	47.40
20 kR + 0.05% EMS	31.06	30.95	31.05	30.94	0.79	0.79	50.55	50.37
20 kR + 0.10% EMS	41.19	40.88	41.18	40.87	0.79	0.79	57.44	51.17
20 kR + 0.15% EMS	40.46	53.36	39.23	53.05	0.68	0.38	56.68	32.00
PK 1029 dry control	17.72	17.65	17.69	17.62	0.79	0.79	42.79	41.49
PK 1029 Presoaked	18.68	18.59	18.65	18.57	0.79	0.79	42.71	42.08
Number of seeds per pod								
20 kR	10.97	11.74	10.21	10.96	0.86	0.87	19.15	20.85
30 kR	13.05	13.16	12.11	12.53	0.86	0.90	23.04	24.41
40 kR	11.54	11.13	10.73	10.57	0.87	0.90	20.26	20.63
0.05% EMS	9.54	10.33	8.43	9.37	0.78	0.82	14.93	17.27
0.10% EMS	8.70	8.84	7.82	7.94	0.80	0.80	14.08	14.35
0.15% EMS	8.38	9.21	7.64	8.56	0.83	0.86	14.11	16.14
20 kR + 0.05% EMS	10.73	11.16	10.08	10.43	0.88	0.87	19.55	19.73

Table 1. Continued.

Treatments	PCV		GCV		H (bs)		GA	
Doses	M_3	M_4	M_3	M_4	M_3	M_4	M_3	M_4
20 kR + 0.10% EMS	10.26	10.81	9.37	10.17	0.83	0.88	17.25	19.54
20 kR + 0.15% EMS	10.37	10.43	9.88	10.01	0.90	0.92	19.38	19.64
PK 1029 dry control	5.59	5.11	2.51	4.50	0.20	0.77	4.46	7.76
PK 1029 Presoaked	7.01	7.12	6.24	6.34	9.79	0.79	11.36	11.52
Harvest index								
20 kR	14.67	14.86	14.54	14.69	0.88	0.87	25.71	26.47
30 kR	15.45	14.54	15.33	13.78	0.88	0.68	27.27	20.59
40 kR	21.07	20.38	20.99	20.22	0.89	0.88	39.47	35.89
0.05% EMS	20.01	19.51	19.93	19.43	0.89	0.89	35.89	35.89
0.10% EMS	16.16	15.78	16.09	15.31	0.89	0.84	29.73	26.31
0.15% EMS	15.45	15.25	15.37	14.89	0.88	0.85	25.71	25.00
20 kR + 0.05% EMS	17.74	17.52	17.64	17.36	0.88	0.88	32.35	32.35
20 kR + 0.10% EMS	16.29	15.96	16.21	15.14	0.88	0.79	29.41	25.71
20 kR + 0.15% EMS	14.96	14.73	14.75	14.58	0.87	0.87	25.00	25.00
PK 1029 dry control	10.91	10.73	10.58	10.36	0.84	0.83	18.75	18.18
PK 1029 Presoaked	18.41	18.42	18.16	18.20	0.87	0.87	33.33	33.33
100 seeds weight								
20 kR	16.09	15.75	14.84	14.61	0.85	0.86	28.15	27.83
30 kR	13.01	13.93	12.12	13.44	0.86	0.93	23.22	26.65
40 kR	13.33	18.23	12.58	15.63	0.88	0.86	24.37	20.21
0.05% EMS	14.90	14.44	13.69	13.48	0.84	0.87	25.92	25.93
0.10% EMS	11.64	11.86	10.37	10.39	0.79	0.76	19.03	18.77
0.15% EMS	16.09	16.29	15.05	14.98	0.87	0.84	28.94	28.32
20 kR + 0.05% EMS	11.60	12.43	10.46	11.07	0.81	0.79	19.38	20.33
20 kR + 0.10% EMS	11.57	11.65	10.59	11.04	0.83	0.89	19.92	21.56
20 kR + 0.15% EMS	11.18	11.16	10.17	10.27	0.82	0.84	19.06	19.41
PK 1029 dry control	7.34	6.99	5.55	5.46	0.57	0.61	8.98	9.72
PK 1029 Presoaked	12.42	11.97	11.37	11.27	0.83	0.88	21.84	22.20
Oil contain								
20 kR	7.23	9.96	6.59	9.49	0.82	0.90	14.79	18.58
30 kR	7.08	8.17	6.92	7.43	0.88	0.82	17.05	13.93
40 kR	7.62	8.63	5.83	7.67	0.87	0.79	13.13	14.32
0.05% EMS	8.98	8.38	8.88	7.54	0.89	0.81	15.46	13.98
0.10% EMS	7.49	5.68	7.05	4.72	0.86	0.69	13.47	8.05
0.15% EMS	9.91	5.30	6.74	4.05	0.88	0.58	13.24	6.33
20 kR + 0.05% EMS	8.86	7.74	8.56	7.27	0.87	0.88	19.03	14.04
20 kR + 0.10% EMS	9.22	9.24	8.77	8.70	0.85	0.88	11.83	16.86
20 kR + 0.15% EMS	9.42	6.00	9.13	5.22	0.88	0.75	14.66	9.36
PK 1029 dry control	7.21	4.32	6.51	2.70	0.81	0.39	13.05	5.27
PK 1029 Presoaked	6.93	6.28	5.43	4.95	0.61	0.95	9.29	8.03
Protein content								
20 kR	4.99	4.49	4.58	4.26	0.84	0.82	8.64	7.99
30 kR	3.83	3.78	3.21	3.38	0.70	0.80	5.55	6.26
40 kR	5.10	5.30	4.84	4.97	0.89	0.85	9.44	7.55
0.05% EMS	4.38	4.23	3.82	3.84	0.76	0.82	6.85	7.16
0.10% EMS	4.88	4.73	4.67	4.53	0.91	0.91	9.18	8.95

Table 1. Continued.

Treatments	PCV		GCV		H (bs)		GA	
Doses	M_3	M_4	M_3	M_4	M_3	M_4	M_3	M_4
0.15% EMS	4.80	4.51	4.60	3.92	0.91	0.75	9.08	7.02
20 kR + 0.05% EMS	6.20	5.20	5.87	4.85	0.89	0.89	11.44	11.37
20 kR + 0.10% EMS	5.99	5.68	5.46	5.10	0.83	0.80	10.25	9.43
20 kR + 0.15% EMS	3.99	4.62	3.59	3.25	0.81	0.80	6.64	5.99
PK 1029 dry control	3.91	3.77	3.26	3.26	0.69	0.74	5.59	5.80
PK 1029 Presoaked	4.52	4.12	4.01	3.98	0.79	0.82	7.35	7.38

For plant height high PCV (20.45), GCV (19.59) were recorded in 40 kR, highest genetic advance (32.75) in 20 kR over PK 1029 dry check and highest heritability (0.89) was noticed in 30 kR in M_3 generation over both checks whereas in M_4 generation, highest PCV (19.70), GCV (19.49) in 40 kR, highest heritability (0.89), in 30 kR and highest genetic advance (33.57) were recorded in 20 kR over PK 1029 dry control (14.89). Highest PCV, GCV, heritability and genetic advance for plant height were observed in 40 kR doses of gamma rays than their respective control. These results are in agreement with the earlier finding [8] in chickpea. For primary branches per plant, highest PCV (17.77), GCV (10.91) in 20 kR + 0.15% EMS and highest genetic advance (18.64) was recorded in 0.05% EMS, highest geritability (0.69) in kR + 0.10% EMS over PK 1029 dry control in M_3 generation while highest PCV, GCV were recorded in 20 kR + 0.15% EMS, highest heritability (0.65) and genetic advance (20.16) were recorded in 20 kR + 0.05% EMS, over both control in M_4 generation. Similar findings were also reported by Chandra et al. [8] in chickpea.

In M_3 generation, highest PCV (36.49) and GCV (36.47) were recorded in 20 kR + 0.15% EMS over PK 1029 dry control, highest heritability (0.79) were recorded in all mutagenic treatments and highest genetic advance (60.44) in 20 kR + 0.15% EMS, over the control for total dry matter whereas in M_4 generation , highest PCV (36.72) and GCV (36.71) were recorded in 20 kR + 0.05% EMS over PK 1029 dry control, highest heritability (0.79) were noticed in all mutagenic treatments over both control and highest genetic advance (56.51) was showed in 20 kR + 0.15% EMS. The treatment 20 kR + 0.15% of EMS showed highest PCV, GCV, heritability and genetic advance for total dry matter per plant than their respective control in both generation. For number of pods per plant in M_3 generation, highest PCV (41.19), GCV (41.18) and genetic advance (57.44) were recorded in 20 kR + 0.10% EMS over PK 1029 dry control while highest heritability (0.79) were noticed in all the mutagenic treatment over the both control. In M_4 generation, highest PCV (40.88) and GCV (40.87) were recorded in 20 kR + 0.10% EMS over PK 1029 dry control. High heritability (0.79) was noticed in all mutagenic treatment over control and highest genetic advance (51.40) was recorded in 20 kR, over control PK 1029 dry. Among all the irradiated populations, 20 kR + 0.10% EMS exhibited highest PCV, GCV, heritability and genetic advance for number of pods per plant in M_3 and M_4 generation followed by 0.10% EMS and 30 kR which supported by Patial et al. [3] and Chandra et al. [8].

In M_3 generation, highest PCV (13.05), GCV (12.11), genetic advances (23.04) were recorded in 30 kR, highest heritability (0.90) in 20 kR + 0.15% EMS over PK 1029 dry control (0.20) for number of seeds per pod whereas in M_4 generation, highest PCV (13.16), GCV (12.53) and genetic advance (24.41) in 30 kR, highest heritability (0.92) was recorded in 20 kR + 0.15% EMS over PK 1029 dry control. Among all treatments, 30 kR exhibited highest positive sift in all genetic parameters for number of seeds per pod than their respective control. Similar findings were also reported earlier [3, 7]. In M_3 generation, highest PCV (21.07), GCV (20.99), highest heritability (0.89), highest genetic advance (39.47) were recorded in 40 kR for harvest index over PK 1029 dry control whereas in M_4 generation, highest PCV (20.38), GCV (2022), genetic advance (35.89) were recorded in 40 kR over the PK 1029 dry control and highest heritability (0.89) were noticed in 0.05% EMS, over the respective control. The highest heritability and genetic advance were exhibited in 40 kR for harvest index. These finding are similar to the earlier findings [8].

In M_3 generation, highest heritability (0.88) in 40 kR and highest genetic advance (28.94) was recorded in 0.15% EMS, over the PK 1029 dry control for 100 seed weight. In M_4 generation, highest PCV (18.23) and GCV (15.63) were recorded in 40 kR, highest heritability (0.93) in 30 kR and highest genetic advance (27.83) was recorded in 20 kR, over the PK 1029 dry control. These results are in agreement with the findings [7, 8] who reported high heritability and genetic advance for 100 seed weight. In M_3 generation, highest PCV (6.20), GCV (5.87) and genetic advance (11.44) were recorded in 20 kR + 0.05% EMS for protein content and highest heritability (0.91) was recorded in 0.10% EMS and 0.15% EMS, over the PK 1029 dry control (0.69). In M_4 generation, highest PCV (5.30) and GCV (4.97) were recorded in 40 kR, highest heritability (0.91) in 0.10% EMS and highest genetic advance (11.37) was recorded in 20 kR + 0.05% EMS, over the respective control. In all irradiated populations, 20 kR + 0.05% EMS treatment is most effective for protein content than their respective control. Similar findings were also reported by Badere and Choudhary [9] for this trait. In M_3 generation, highest PCV (9.91), GCV (6.74) were recorded in 0.15% EMS, highest heritability (0.89) in 0.05% EMS and highest genetic advance (19.03) in 20 kR + 0.05% EMS over the PK 1029 presoaked control. In M_4 generation, highest PCV (9.96), GCV (9.49) were recorded in 20 kR, highest heritability (0.90) in 20 kR and highest genetic advance (18.58) was recorded in 20 kR over PK 1029 dry control for oil contain in soybean.

In M_3 generation, highest PCV (32.34) and GCV (31.32) were observed in 40 kR whereas the lowest PCV (6.98) and GCV (5.45) were recorded in PK 1029 dry control. Highest heritability (0.89) was recorded in 0.15% EMS, whereas lowest heritability recorded in PK 1029 presoaked control (0.67). The highest genetic advance (53.92) was recorded in 0.15% EMS, whereas lowest genetic advance (13.47) recorded in PK 1029 presoaked control. In M_4 generation, highest PCV (29.65) and GCV (29.24) were observed in 40 kR over the control PK 1029 dry. High heritability (0.89) and highest genetic advance (53.56) were noticed in 0.05% EMS, over the control PK 1029 presoaked (0.69) heritability and (11.79) genetic advance respectively. Similar findings were reported by Patial et al. [7] and Chandra et al. [8] for seed yield.

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