



Gamma rays and EMS induced mutants in Indian mustard (*Brassica juncea*)

Beena Nair, AT Nartam, MG Badukale¹ and NA Mohurle¹

AICRP on Mustard, College of Agriculture, Nagpur, Maharashtra, India

¹P.G. Students, Botany Section, College of Agriculture, Nagpur, Maharashtra, India

(Received: 7 Nov 2016; Revised: 21 Nov 2016; Accepted: 5 Dec 2016)

Abstract

Seeds of *Brassica juncea* (L.) cultivar BIO 902 and Pusa Bold were treated with EMS (0.5%) and gamma rays (900-1300 Gy) with the objective to study the variability for qualitative and quantitative traits, to isolate morphological and economical mutants in M₂ generation. Morphological mutants viz., early and late maturing, branched, appressed, tall and dwarf, powdery mildew tolerant and aphid tolerant and high yielding mutants were identified. These mutants were isolated from all the treatments of gamma rays (900-1300 Gy) and combination treatment of gamma rays and EMS (0.5%). These selected mutants will be forwarded to M₃ and further generations until homozygosity is reached and superior progenies will be evaluated in yield trials.

Key words: *Brassica juncea*, mutation, gamma rays, EMS

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is considered as one of the most important vegetable oil and protein meal crop in Indian subcontinent. To fulfil the ever-increasing demand of oil, seed and oilyield needs to be improved. Yield is one of the most important economic characters and is the product of multiplicative interaction of contributing characters. Hence, the important objective in mustard improvement is oriented to develop varieties which have high yielding potential (Labana and Banga, 1984). Also, there is compelling need to increase and stabilize the productivity of Indian mustard (Meena *et al.*, 2015). The other objectives are oriented to develop new varieties with wider adaptability, early maturity, disease resistance and high oil content along with high yield potential. Mutation breeding is one of the approaches to enhance spectrum of variability for characters of agronomic and economic importance (Jambhulkar and Shitre, 2007). The objective of this study was to induce mutation to study the variability M₂ for qualitative and quantitative characters and to identify the superior desirable mutants in M₂ generation.

Materials and Methods

Dry healthy and genetically pure seeds of *Brassica*

juncea cultivars BIO 902 & Pusa Bold were divided into six lots of 300 seeds each for giving the gamma rays treatment separately. These 600 seeds of selected variety were subjected to irradiation with 900, 1000, 1100, 1200 and 1300 Gy (Co⁶⁰ at BARC). The 300 seeds of each treatment were treated with 0.5% aqueous solution of EMS after pre-soaking with sterilized distilled water for 12 hours.

The treated seeds along with one control of dry and another of water soaked were sown in the field to raised M₁ generation in non replicated trial. M₁ generation was screened for different morphological mutants and seeds from each M₁ generation were harvested separately.

M₂ generation was raised during *Rabi* 2015. Twelve treatments included different doses of gamma rays alone and combination of gamma rays and EMS along with control of mustard variety BIO 902 & Pusa Bold. 30 M₂ plants were selected at random per treatment to record the observations on yield and yield components. 30 observational plants were scored in field and plants were rated in 0-9 scale for powdery mildew infestation (Anonymous, 2015). Based on the score of this, incidence percent disease intensity was determined. Arc sin transformations were done for data analysis. Ten observational plants

were scored in field and plants were rated in 0-5 for aphid infestation (Bakhetia and Sandhu, 1977). Based on this score of aphid infestation, mean score was determined. Square root transformation was done for data analysis. All the recommended practices were followed to raise a good crop the experimental plot was deliberately sown late for powdery mildew to occur, as late sown crop has maximum powdery mildew incidence. No plant protection measures were under taken in order to screen for powdery mildew and aphid resistance. The treated populations were carefully screened for morphological mutants and were scored treatment wise.

Results and Discussion

Mutation frequency of each visible mutant in M_2 generation was calculated as suggested by Gaul (1958) and is represented in table 1a. The table revealed that for variety BIO 902 the treatment T_{12} (0.5% EMS and 1300 gy gamma rays) induced the highest mutation frequency (7.67%) followed by T_{10} (0.5% EMS and 1100 gy gamma rays) of 7.16%, and the lowest (3.12%) was found in T_3 (900 gy gamma rays). The frequency of mutation was

comparable in all treatments. Tall mutants were of maximum occurrence (7.96%), and maximum of 1.78% of tall mutants were observed in 1100 gy gamma rays treatment followed by combination treatment of (0.5% EMS and 1300 gy gamma rays). 6.35% of mutants were identified as early maturing and 1.91% of them were from treatment T_5 (1100gy gamma rays). High yielding mutants were of maximum occurrence in treatment T_{12} (0.5% EMS and 1200 gy gamma rays). Aphid tolerant mutants were found in almost all the treatments and maximum occurrence was found in treatment T_9 (0.5% EMS and 1000gy gamma rays). Powdery mildew tolerant mutants were identified from treatment T_5 (1100gy gamma rays), T_3 (900gy gamma rays) and T_7 (1300gy gamma rays) and bold seeded mutants were identified in 900 and 1000gy gamma rays and their combination treatments with 0.5% EMS ie treatments T_3 , T_4 , T_8 and T_9 respectively. Bold seeded mutants were also found in treatments T_5 (1100gy gamma rays and T_{11} (0.5% EMS and 1200 gy gamma rays).

Mutation frequency (Table 1b) of each visible mutant

Table 1a: Frequency of induced mutants in different treatments of EMS and gamma rays in M_2 generation (BIO 902)

Type of mutation	T_3 900 Gy	T_4 1000 Gy	T_5 1100 Gy	T_6 1200 Gy	T_7 1300 Gy	T_8 0.5% EMS and 900 Gy	T_9 0.5% EMS and 1000 Gy	T_{10} 0.5% EMS and 1100 Gy	T_{11} 0.5% EMS and 1200 Gy	T_{12} 0.5% EMS and 1300 Gy	Total
Varigated	0.65	2.03	-	-	0.96	-	-	0.74	0.12	-	4.5
Dwarf	-	-	-	-	-	1.86	0.67	-	-	-	2.53
Tall	0.47	0.68	1.78	1.51	0.87	-	-	1.03	-	1.62	7.96
Late flowering	-	-	-	-	-	-	1.64	0.90	-	1.82	4.36
Early maturing	0.54	0.61	1.91	0.65	0.73	0.58	-	-	1.33	-	6.35
Late maturing	-	-	-	-	0.28	-	0.63	1.20	-	0.77	2.88
High yielding	0.15	0.65	0.47	-	0.19	0.36	0.14	0.29	1.03	1.26	4.54
More branch	-	1.08	-	0.42	0.75	-	-	0.10	-	0.56	2.91
Long siliqua	-	-	0.55	-	0.74	-	0.22	0.70	-	0.46	2.67
Bold seeded	0.44	1.10	0.69	-	-	0.51	0.37	-	0.81	-	3.92
Aphid tolerant	0.36	0.52	0.87	0.43	0.28	0.54	1.10	0.92	0.45	0.37	5.84
Powdery mildew tolerant	0.22	-	0.36	-	0.14	-	-	-	-	-	0.72
Appressed	0.29	0.26	0.47	0.39	0.55	0.60	0.43	0.84	0.27	0.63	4.73
Short siliqua	-	-	-	0.35	0.52	0.42	0.39	0.44	0.32	0.18	2.62
	3.12	6.93	7.1	3.75	6.01	4.87	5.59	7.16	4.33	7.67	56.53

Table 1b: Frequency of induced mutants in different treatments of EMS and gamma rays in M₂ generation (Pusa Bold)

Type of mutation	T ₁ 900gy gamma rays	T ₂ 1000gy gamma rays	T ₃ 1100gy gamma rays	T ₄ 1200gy gamma rays	T ₅ 1300gy gamma rays	T ₇ 900gy gamma rays + .5% EMS	T ₈ 1000gy gamma rays + .5% EMS	T ₉ 1100gy gamma rays + .5% EMS	T ₁₀ 1200gy gamma rays + .5% EMS	T ₁₁ 1300gy gamma rays + .5% EMS	Total
Varigated	1.85	-	0.89	-	-	-	-	-	-	0.35	3.09
Dwarf	0.30	0.25	0.10	-	-	-	0.55	0.26	1.50	-	2.96
Tall	-	-	0.20	0.82	1.68	0.42	0.24	-	-	-	3.36
Late flowering	1.45	0.89	0.34	-	-	-	0.20	-	-	0.90	3.78
Early maturing	0.45	-	-	-	-	0.75	1.76	-	-	-	2.96
Late maturing	1.00	0.26	-	-	-	-	-	-	0.20	0.45	1.91
High yielding	0.14	1.95	0.10	0.46	0.12	0.65	0.28	0.58	-	-	4.28
More branch	0.10	1.00	-	-	-	0.15	1.20	-	0.13	-	2.58
Sterile	-	-	-	-	-	-	0.78	-	-	-	0.78
Long siliqua	0.56	0.42	0.10	-	-	-	-	0.14	0.40	0.13	1.75
Bold seeded	0.10	0.38	-	-	0.19	-	-	-	0.56	1.00	2.23
Aphid tolerant	-	0.46	-	0.35	-	-	-	-	-	-	0.81
Powdery mildew tolerant	-	-	0.32	0.38	-	-	-	-	-	-	0.70
Apressed	0.50	-	-	-	0.75	0.10	-	-	0.33	0.12	1.80
Short siliqua	-	-	-	-	0.10	-	0.25	-	0.16	0.45	0.96
Yellow seeded	-	-	-	-	-	-	-	-	0.80	-	0.80
	6.45	5.61	2.05	2.01	2.84	2.07	5.26	0.98	4.08	3.40	34.75

in M₂ generation for Pusa Bold variety revealed that the treatment T₁ (900 gy gamma rays) induced the highest mutation frequency (6.45%) followed by T₂ (1000 gy gamma rays) of 5.61% the lowest in T₉ (0.5% EMS and 1100gy gamma rays) of 0.98%. The frequency of mutation was comparable in all the treatments. High yielding mutants were of maximum occurrence i.e 4.28%, and treatment T₂ (900 gy gamma rays) had maximum frequency of 1.95%. These mutants were found in all treatments except T₁₀ & T₁₁ i.e combination treatment of 0.5% EMS and 1200 gy gamma rays and 1300 gy gamma rays. Tall mutants were observed in treatments T₃, T₄, T₅, T₇ & T₈ i.e 1100gy, 1200gy & 1300gy gamma rays and combination treatment of 0.5 % EMS and 900gy & 1000gy gamma rays respectively. Dwarf mutants were found in treatments of 900 gy gamma rays (T₁), 1000gy gamma rays (T₂), 1100gy gamma rays (T₃), combination treatments of 0.5% EMS and 1000gy gamma rays (T₈), 1100gy gamma rays (T₉)

& 1200gy gamma rays (T₁₀). Bold seeded mutants were identified in treatments (T₁) 900gy gamma rays, (T₂) 1000gy gamma rays, (T₅) 1300gy gamma rays, combination treatments of 0.5% EMS and 1200gy gamma rays (T₁₀) and 1300gy gamma rays (T₁₁). Aphid tolerant mutants were found in only two treatments of 1000gy gamma rays (T₂) & 1200gy gamma rays (T₄). Powdery mildew tolerant mutants were also identified in only two treatments i.e 1100gy & 1200gy gamma rays (T₄ & T₅) respectively.

Increase in frequencies over character with increase in doses of gamma rays and EMS in combination mustard was observed by Sangsir *et al.* (2005). Similar results were also observed by Girijia *et al.* (2013) in *B. juncea* when treated with gamma rays and EMS which gave highest frequency in seed yield of mustard.

Mutation frequency did not show any specific trend

Table 2a: Performance of selected mutants in M₂ generation (Pusa Bold)

Treatment	Plant No.	Characters	Days to maturity (days)	Plant height (cm)	No. of branches plant ⁻¹	No. of siliqua plant ⁻¹	1000 seed weight (g)	PDI of PM infestation (%)	Mean Aphid Score	Seed yield plant ⁻¹ (g)
T ₁ (Untreated, Control) mean			121	114	4.20	37.10	2.98	38.1 (s)	1.3(R)	3.1
T ₃ (900 Gy)	8	High yield, Early, Aphid resistant	115	160	5	101	3.2	30.0 (s) (23.9)	0.3(HR) (0.5)	9.9
	12	High yield	130	150	8	160	4.2	42.0 (s) (26.8)	-	12.4
	16	High yield	125	130	8	126	3.2	47.1 (s) (29.1)	-	11.3
	18	Early	105	181	7	140	2.8	26.0 (s) (30.1)	-	12.3
	23	Powdery mildew tolerant	118	155	6	140	3.9	20.3 (MR) (32.4)	-	13.2
T ₄ (1000 Gy)	1	Powdery mildew resistant	120	168	6	110	3.1	0.0 (I) (21.9)	2.3(MR) (1.5)	8.5
	2	Aphid resistant	118	156	5	75	3.3	32.0 (S) (24.0)	0.1(HR) (0.3)	5.3
	3	Aphid resistant	120	166	6	65	2.4	42.0 (S) (25.4)	0.4(HR) (0.6)	4.8
	5	More no. of branches	120	165	7	118	2.2	40.0 (S) (27.3)	1.3(HR) (1.1)	10.0
	7	High yield	120	155	7	105	3.9	30.0 (S) (28.7)	1.5(R) (1.2)	8.4
	9	More no. of branches, Aphid resistant	120	174	8	120	4.0	34.0 (S) (29.8)	0.3(HR) (0.5)	10.1
	14	Bold, Powdery mildew tolerant	120	140	7	135	3.3	20.0 (MR) (31.9)	-	12.0
	18	Early	105	150	5	55	4.1	48.0 (S) (33.3)	-	3.8
	21	Early	108	135	7	73	3.4	54.3 (HS) (34.1)	-	5.5
	22	Dwarf, High yield	120	92	8	120	4.2	30.0 (S) (34.4)	-	11.5
	24	Powdery mildew resistant	120	115	4	65	3.8	0.0 (I) (34.9)	-	4.9
	25	Powdery mildew resistant	125	148	4	70	2.7	0.0 (I) (35.2)	-	5.1
	30	Long siliqua, Bold	120	155	6	122	3.9	66.7 (HS) (36.4)	-	10.9
T ₅ (1100 Gy)	3	Long Siliqua, Aphid resistant	105	148	5	86	3.3	24.0 (MR) (30.3)	0.4(HR) (0.6)	5.3
	5	Aphid resistant	120	170	5	70	2.9	45.7 (S) (31.5)	0.2(HR) (0.4)	5.2
	7	Aphid resistant	120	145	4	120	3.0	31.1 (S) (32.4)	0.2(HR) (0.4)	9.9
	12	Aphid Tolerant	120	196	7	172	3.4	38.0 (S) (33.9)	-	15.6
	18	High yield	120	180	7	155	3.5	48.0 (S) (35.2)	-	13.8
	28	powdery mildew resistant	120	115	5	60	4.5	0.0 (I) (36.8)	-	7.3

	29	powdery mildew resistant	105	130	5	70	2.9	0.0 (I) (37.0)	-	4.8
T ₆ (1200 Gy)	3	Early, Aphid resistant	105	135	6	54	3.1	50.0 (S) (33.4)	0.0(HR) (0)	4.7
	5	Early	105	170	9	300	4.3	23.3 (MR) (34.2)	1.6(R) (1.3)	23.5
	7	Aphid resistant, Powdery mildew resistant	120	165	5	63	3.5	0.0 (I) (34.7)	0.0(HR) (0)	4.7
	22	Early, Appressed	115	180	4	66	3.7	40.0 (S) (36.8)	-	4.8
T ₇ (1300 Gy)	1	Powdery mildew resistant	120	135	6	40	2.5	0.0 (I) (34.4)	0.4(HR) (0.6)	3.1
	3	Aphid resistant	120	124	5	20	3.3	10.0 (R) (35.3)	0.2(HR) (0.44)	2.3
	5	Aphid resistant	120	150	3	45	3.2	48.0 (S) (35.8)	0.3(HR) (0.54)	3.4
	6	More No. of Branches, Powdery mildew tolerant, Aphid resistant	120	125	8	47	2.0	14.0 (MR) (35.9)	0.0(HR) (0)	3.5
	7	Aphid resistant	120	130	6	45	2.7	40.0 (S) (36.1)	0.0(HR) (0)	3.3
	8	Aphid resistant	120	160	5	43	3.1	40.0 (S) (36.2)	0.0(HR) (0)	3.4
	10	High yield, Aphid resistant	120	115	8	102	3.9	22.0 (MR) (36.5)	0.0(HR) (0)	7.6
	13	More no. of branches	115	165	9	132	2.9	36.0 (S) (36.7)	-	11.3
	17	High yield	120	145	5	130	2.9	64.0 (HS) (37.0)	-	11.5
	28	More no. of siliqua	130	143	6	120	3.2	60.0 (HS) (37.7)	-	10.5
T ₂ (water soaked, Control) mean			121	122.20	5.60	43.50	3.21	38.1 (S)	1.3(R)	3.5
T ₈ (0.5% EMS and 900 Gy)	3	Aphid resistant	120	156	5	67	3.1	50.0 (S) (36.5)	0.4(HR) (0.6)	3.7
	6	More no. of Branches, Aphid resistant	120	152	8	180	3.3	64.4 (HS) (36.8)	0.6(HR) (0.8)	17.2
	12	High yield	120	115	4	150	4.4	32.9 (S) (37.3)	-	12.1
	14	High yield	125	140	7	125	4.0	48.9 (S) (37.4)	-	11.7
	24	High yield	120	150	7	170	3.9	58.0 (HS) (37.7)	-	16.4
T ₉ (0.5% EMS and 1000 Gy)	2	More no. of siliqua	120	130	6	130	2.9	68.6 (HS) (37.0)	1.5(R) (1.2)	11.3
	5	Appressed, Aphid resistant	120	145	5	170	2.4	48.0 (S) (37.3)	1.0(HR) (1)	16.0
	9	Aphid Resistant, Long siliqua	120	150	5	168	3.2	71.4 (HS) (37.5)	0.4(HR) (0.6)	16.1
	14	Bold, late	140	150	5	128	4.4	43.3 (S) (37.7)	-	11.3
	23	Long siliqua	120	150	3	55	2.6	56.7 (HS) (37.9)	-	3.7

T ₁₀ (0.5% EMS and 1100 Gy)	1	Tall, Bold	120	170	5	112	4.5	20.0 (MR) (37.4)	0.0(HR) (0)	9.8
	4	Appressed	120	145	5	110	2.6	44.0 (S) (37.6)	1.6(R) (1.26)	9.7
	10	Tall	120	170	5	120	3.3	30.0 (S) (37.8)	0.3(HR) (0.54)	10.3
	19	Tall	120	185	5	115	2.8	44.0 (S) (37.9)	-	8.2
	29	Appressed	125	146	7	135	2.0	52.0 (HS) (38.1)	-	12.3
T ₁₁ (0.5% EMS and 1200 Gy)	3	Bold, aphid Resistant	120	140	3	40	4.1	36.7 (S) (37.8)	0.5(HR) (0.70)	3.4
	18	High yield	130	120	5	148	4.1	44.0 (S) (38.0)	-	13.6
	20	Long Siliqua, High yield	120	140	3	97	3.2	50.0 (S) (38.0)	-	7.4
	26	Early	110	140	4	110	3.0	52.0 (HS) (38.1)	-	8.7
	28	Appressed	120	140	6	95	2.5	48.6 (S) (38.1)	-	7.1
	30	Bold	120	130	3	96	4.3	66.7 (HS) (38.1)	-	7.3
T ₁₂ (0.5% EMS and 1300 Gy)	2	More siliqua	120	140	4	145	2.1	63.3 (HS) (37.9)	1.4(R) (1.18)	13.3
	4	Tall	125	180	4	80	3.7	26.7 (S) (37.9)	0.4(HR) (0.63)	5.5
	6	More no. of Branches, early	115	135	6	90	3.4	44.0 (S) (38.0)	0.4(R) (0.63)	6.6
	8	Appressed, Long Siliqua	120	160	3	35	2.4	64.0 (HS) (38.0)	0.4(R) (0.63)	3.0
	12	More no. of siliqua	120	155	4	135	2.5	42.2 (S) (38.0)	-	11.5
	15	Tall, More no. of siliqua	118	170	5	100	3.1	44.0(S) (38.1)	-	7.5
	16	Tall	125	178	6	110	3.7	51.4 (HS) (38.1)	-	8.9
	20	High yield	125	140	5	120	3.3	48.0 (S) (38.1)	-	10.3
23	Appressed	115	135	5	105	2.7	40.0 (S) (38.1)	-	7.9	

Table 2b Performance of selected mutants selected in M₂ generation (BIO 902).

Treatment	Plant no	Charecters	Days to maturity	Plant Height	No of Branches	No of Siliqua	PDI of PM infestation	Score of Aphid infestation	Seed Yield
T ₁ (900 Gy)	2	Bold, High yield	121	125	5	138	41.1(S) (36.2)	2.8(MR) (1.67)	25.3
	5	Aphid resistance	122	160	1	62	50.0(S) (36.7)	0(HR) (0)	16.7
	6	Early	105	163	1	45	40.0(S) (36.8)	2.5(MR) (1.58)	19.8
	7	Early, more branch	107	135	5	230	66.7(HS) (36.9)	0.2(HR) (0.45)	26.8
	8	Early	118	160	4	135	58.9(HS) (37.0)	2.8(MR) (1.67)	22.0
	10	More branch	120	145	2	150	52.9(HS) (37.1)	3.3(S) (1.82)	24.0

T ₂ (1000 Gy)	11	More branch	122	125	4	135	54.4(HS) (37.2)	-	20.1
	16	More branch	123	130	5	135	41.1(S) (37.5)	-	18.5
	18	More branch	123	181	5	175	46.7(S) (37.5)	-	19.2
	1	High yield	116	168	3	158	42.9(S) (36.8)	1.6(R) (1.26)	22.5
	10	Early, more branch	98	145	3	130	50.0(S) (37.6)	2.4(MR) (1.55)	18.9
	13	Aphid resistance	120	162	2	120	41.1(S) (37.7)	0(HR) (0)	14.3
	14	Aphid resistance, early	110	140	1	92	43.3(S) (37.7)	0(HR) (0)	16.2
	18	Aphid resistance	122	150	2	75	51.1(HR) (37.8)	0(HR) (0)	13.4
	19	Small siliqua	102	178	2	72	45.6(S) (37.8)	-	20.1
	25	Aphid resistance	121	148	3	93	37.8(S) (37.9)	0(HR) (0)	15.6
T ₃ (1100 Gy)	29	Early, Aphid resistance	102	160	3	121	51.1(HS) (38.0)	0(HR) (0)	13.5
	8	Early, Tall	105	140	3	115	46.7(S) (37.7)	2.4(MR) (1.55)	19.9
	9	Short siliqua, more siliqua	116	175	2	128	43.3(S) (37.8)	3.4(S) (1.84)	18.2
	10	Bold seed	120	165	3	112	50.0(S) (37.8)	2.4(MR) (1.55)	24.3
	11	Aphid resistance	121	200	3	97	37.1(S) (37.8)	0(HR) (0)	18.2
	13	More siliqua, early	98	202	3	166	44.4(S) (37.9)	-	26.0
	14	More siliqua, bold	119	166	3	178	42.9(S) (37.9)	-	22.3
	16	Powdery mildew resistance, Aphid resistance	126	175	3	126	0(Immune) (0)	0(HR) (0)	23.0
	17	Long siliqua	122	184	4	122	47.8(S) (37.9)	-	20.2
	18	Aphid resistance	120	180	1	104	34.0(S) (37.9)	0(HR) (0)	16.2
T ₄ (1200 Gy)	22	Long siliqua more branch	121	150	5	144	40.0(S) (38.0)	-	24.2
	29	More siliqua, Aphid resistance	120	130	4	134	37.8(S) (37.8)	0(HR) (0)	20.4
	30	More siliqua	124	142	2	123	47.8(S) (38.1)	-	22.2
	5	PM resistance	119	170	3	78	0(immune) (0)	1.6(R) (1.2649)	16.2
	13	PM resistance	101	165	3	96	0(immune) (0)	-	14.6
	15	Bold	105	115	2	106	33.3(S) (38.0)	-	18.1
	16	PM resistance	98	125	5	310	0(immune) (0)	-	19.2
	17	Bold basal branch	120	160	7	374	66.7(HS) (38.0)	-	22.1
	18	More siliqua basal branch	119	140	8	783	53.3(HS) (38.0)	-	24.2

	19	Long siliqua	116	166	5	194	52.2(HS) (38.0)	-	17.9
	22	Early more branch	106	180	5	255	45.6(S) (38.0)	-	17.8
T ₅ (1300 Gy)	18	Appressed	120	210	1	105	38.9(S) (38.1)	-	20.8
	21	Appressed, early	105	140	1	157	53.3(HS) (38.1)	-	20.8
	27	Early more siliqua	122	140	3	145	56.0(HS) (38.1)	-	21.8
	28	Short siliqua, Early	101	143	2	105	41.1(S) (38.1)	-	19.2
	29	Apressed	119	135	3	150	48.9(S) (38.1)	-	25.5
T ₆		Dry control	119.5	114	2.7	72	71.4(HS) (38.0)	2.7(MR) (1.64)	17.5
T ₇ (0.5% EMS and 900 Gy)	1	Apressed more siliqua	120	155	3	263	40.0(S) (13.9)	2.9(MR) (1.7029)	28.0
	5	Bold seed and dwarf	112	145	2	83	31.4(S) (21.1)	1.9(R) (1.3784)	19.1
	6	Long siliqua	110	152	2	182	64.4(HS) (22.1)	1.9(R) (1.3784)	21.1
	7	Apressed and more siliqua	117	115	2	120	68.9(HS) (23.1)	2.1(MR) (1.4491)	18.2
	14	Apressed	124	135	1	48	65.7(HS) (27.9)	-	19.0
	19	More siliqua	121	111	4	130	50.0(S) (30.6)	-	18.2
	21	More branches	116	110	5	201	73.3(HS) (31.5)	-	21.0
	29	Short siliqua	116	96	2	56	71.4(HS) (34.8)	-	18.2
T ₈ (0.5% EMS and 1000 Gy)	7	Bold	127	150	2	172	37.1(S) (34.4)	0.1(HR) (0.32)	23.9
	9	High yield	112	150	4	182	44.3(S) (29.8)	3.4(S) (1.84)	18.0
	20	High yield	122	160	3	134	47.8(S) (32.3)	-	20.0
	22	More branches, high yield	118	110	3	165	45.6(S) (34.4)	-	25.0
	24	High yield	123	120	1	76	43.3(S) (34.9)	-	20.5
	25	High yield	112	143	2	80	40.0(S) (35.2)	-	18.6
	27	High yield	112	136	1	125	47.8(S) (35.7)	-	19.1
	28	High yield	124	140	1	124	45.7(S) (35.9)	-	20.9
T ₉ (0.5% EMS and 1100 Gy)	1	High yield, more branches, early	97	170	5	252	42.2(S) (27.9)	0.1(HR) (0.32)	28.2
	2	High yield, apressed	122	170	3	138	55.6(HS) (30.3)	3.7(S) (1.92)	20.3
	10	High yield	115	170	5	118	41.1(S) (33.4)	3.4(S) (1.8)	18.5
	30	High yield	119	165	3	102	44.4(S) (37.1)	-	21.0
T ₁₀ (0.5% EMS)	1	Yellow seeded, Short Siliqua	95	145	3	177	38.6(S) (31.9)	3.2(S) (1.79)	25.4

and 1200 Gy)	2	High yield	115	135	4	153	61.1(HS) (31.9)	3.9(S) (1.97)	24.3
	4	Yellow seeded, High yielding	120	165	5	305	40.0(S) (33.8)	3.4(S) (1.84)	29.5
	5	Small seed, late	126	175	4	105	40.0(S) (34.2)	3.4(S) (1.84)	20.3
	6	Yellow seeded, Tall	95	150	5	255	42.2(S) (34.4)	3.9(S) (1.97)	21.7
	7	Yellow seeded	95	150	4	180	37.8(S) (34.7)	1.8(R) (1.34)	22.0
	8	Yellow seeded	114	125	2	112	50.0(S) (34.9)	3.8(S) (1.95)	18.1
	24	More siliqua, small seed	116	150	3	137	58.9(HS) (36.9)	-	21.0
	25	More branch, small seed, dwarf	119	145	4	178	54.4(HS) (37.1)	-	25.2
	27	More branch	120	145	2	240	51.1(HS) (37.3)	-	20.3
	28	More branch	122	140	3	376	52.2(HS) (37.4)	-	24.2
	29	More branch	121	120	4	138	52.2(HS) (37.4)	-	19.1
T ₁₁ (0.5% EMS and 1300 Gy)	1	Late maturity	126	125	3	218	51.1(HS) (34.4)	1.5(R) (1.2247)	22.2
	6	High yield	115	135	4	123	35.6(S) (35.9)	2.8(MR) (1.6733)	19.9
	16	Apressed	96	160	3	145	47.8(S) (37.0)	-	18.0
	22	Long siliqua	112	145	1	116	50.0(S) (37.4)	-	19.1
T ₁₂		Water soak control	118	122.2	2.7	85.5	57.8(HS) (38.1)	2.21(MR) (1.48)	17.8

with increase in doses of mutagen. High yielding, early maturing, tall, bold seeded, powdery mildew tolerant and aphid tolerant mutants were identified in both the varieties of Pusa Bold and BIO 902, but dwarf mutants were identified only in Pusa Bold variety. Mohamed and Haleem (2014) indicated significantly differential response of cultivars to radiation treatments. The treatments of gamma rays alone in general, showed the higher effectiveness than combination treatment of EMS and gamma rays in Pusa bold.

Elimination of low potential breeding material is always advantage because such elimination enhances the probability of finding superior mutants in remaining material. Selection of superior mutants, based on single character of seed yield may not be effective and hence inclusions of one or more yield contributing characters like no. of siliqua plant⁻¹, disease pest reaction, and earliness are considered as effective selection criteria. Based on these

criteria, superior mutants from different treatments were selected in the present study and they are furnished in table 2a & table 2b. The better performing M₂ progeny from different treatment were selected based on seed yield plant⁻¹, no of siliqua plant⁻¹, powdery mildew infestation and aphid infestation were selected for forwarding to M₃ generation. Those plants which had high seed yield plant⁻¹ coupled with no of siliqua plant⁻¹ than control were selected since homozygosity will not be attained in M₂ generation.

Total 69 M₂ plants from different treatments of BIO 902 (table 2a) & 79 (table 2b) mutants of Pusa Bold were selected mainly on the basis of seed yield, aphid resistance, powdery mildew resistance and these mutants will be forwarded to M₃ generation in progeny rows for one or more generations, so that homozygosity will be attained and the superior progenies can be selected for forwarding to yield trials in the further generation.

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