Asian Journal of Crop Science

ISSN 1994-7879

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http://www.scialert.net

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Asian Journal of Crop Science 6 (2): 123-132, 2014
ISSN 1994-7879 / DOI: 10.3923/ajcs.2014.123.132

Effectivenss of Gamma Rays to Induce Genetic Variability to Improve Some Agronomic Traits of Canola (*Brassica napus* L.)

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ABSTRACT
Genetic variability is a prerequisite for any effective selection programme. This investigation was conducted to study the effectiveness of different doses of gamma radiation to induce new genetic variability in some agronomic traits of canola to improve the yielding ability via., selection of useful mutants under saline conditions. Homogeneous dry seeds of two canola cultivars, i.e., serw 4 and 6 were treated with 0, 5, 10 and 15 Kr of gamma rays and the resultant M_2 generation was studied under saline field conditions. Results indicated significant mean square due to radiation doses, cultivars and their interaction for most studied traits, indicating the differential response of cultivars to radiation treatments. Higher variation in the treated populations than the control was detected for all studied traits, except for plant height in serw 4 cultivar. The highest variation induced was observed due to the treatment of 15 Kr of gamma rays in most studied traits in serw 4 while in 6, 5 Kr dose came in the first rank for most traits. High positive correlation was obtained between seed yield plant^{-1} and each of No. of branches plant^{-1}, No. of pods plant^{-1} and seed oil% of both cultivars treated by gamma rays. Some promising mutants were isolated in the M_2 generation. These mutants included (a) Mutants for high yielding ability and (b) Early flowering mutants.

Key words: Canola, effectiveness, gamma rays, induce, mutants, genetic variability, agronomic traits, saline conditions

INTRODUCTION
In Egypt, edible oil production covers only about 15% of the annual requirements which is not sufficient to provide the needs of consumption. *Brassica* spp. came in the second rank after soybean in the global oil seed-crop production during the last two decades (Anonymous, 2011a). Furthermore, its seeds are rich source of vegetable oil and ranking third largest source in the world (Anonymous, 2013). World production of rapeseed reached 58.4 million tons in 2010/2011 season (Anonymous, 2011b). Therefore canola is one of the oil crops that can contribute in solving the problem of edible oil shortage in Egypt. This can be achieved by increasing the cultivated acreage of canola in the new reclaimed lands outside the Nile valley and Delta far from the competition of other important winter crops occupied most of the old land. But the new areas frequently suffer from harsh environmental conditions such as salinity. So, it is necessary to select the suitable genotypes with high yield potential and able to grow well under these conditions. The genetic variability is a prerequisite for any selection effective programme. The genetic variability enhances

the opportunities for selection of new desired genotypes. Although, nearly all the mono-genomic *Brassica* sp. are self-incompatible, the natural amphidiploid species *Brassica napus* is self-compatible (Takahata *et al.*, 1980; Rosa *et al.*, 2010). The amphidiploid species *Brassica napus* is largely self-pollinating, so breeding methods developed for highly inbred crops, such as the cereal grains, have been adapted for this species (Anonymous, 2012). Generally, the self-pollinating crops have a very little genetic variability. There are several methods are used in plant breeding to increase the genetic variability, one of these is mutation breeding method. Mutations are important source for inducing variability. Induced mutations have been successfully used for improvement some economic and quality traits during short time (Manjaya and Nandanwar, 2007). Induced mutations have also been very successfully employed in canola and other crop plants to induce genetic variation and isolation the mutants with desired economic traits (Sorour and Keshta, 1994; Javed *et al.*, 2003; Khatri *et al.*, 2005; Sheikh *et al.*, 2009; Siddiqui *et al.*, 2009; Rahimi and Bahrani, 2011; Thagana *et al.*, 2006; Emrani *et al.*, 2012).

This study aimed to study the effectiveness of mutation technique to induce genetic variations in the studied traits of the two cultivars (1) Serw 4 and (2) Serw 6 by gamma rays. Furthermore, isolation of promising mutants with improved traits under the study conditions (saline conditions) was also objective for this study.

MATERIALS AND METHODS

Experimental site describition: A field trial was conducted at the Experimental Farm of Faculty of Agriculture, South Valley Univ., Qena (26°11'N and 32°44'E) during two winter seasons i.e., 2009/2010 and 2010/2011.

Radiation treatment and field trials: Seeds of two canola varieties, i.e., serw 4 and 6 were irradiated by three doses of gamma rays, viz., 5, 10 and 15 Kr from Co^{60} source at the Middle Eastern Regional Radioisotope Center for the Arab Countries, Dokki, Giza. The irradiated seeds and their control were sown in the field to raise M_1 generation. At maturity, 5 siliquas (pods) from each plant were harvested and seed was bulked dose-wise to raise M_2 generation. In the second season, the bulked seeds of each treatment were sown in a randomized complete blocks design with three replicates. Each plot consisted of four rows, 3 m long and 50 cm apart, sowing was in hills spaced 10 cm. All the recommended agronomic practices were used. The saline conditions are soil and irrigation water salinity (EC) which were 16.33 and 7.59 ds m^{-1}, respectively.

Measurements: In each plot, number of days to 50% flowering was recorded. At harvest data, from 16 random plants were recorded on plant height (cm), No. of primary branches $plant^{-1}$, No. of siliquas $plant^{-1}$, seed yield $plant^{-1}$ (g) and 1000-seed weight (g). Seed oil content was estimated by Soxhelt apparatus according to AOAC (1980).

Statistical analysis: Data were statistically analyzed using analysis of variance for RCBD according to Gomez and Gomez (1984). Estimates of mean ($\bar{X}$), standard deviation (S), Coefficient of Variation (CV) and range were calculated. Genotypic correlation analysis between the studied traits also was performed according to Miller *et al.* (1958) from the corresponding variance and covariance components as follow:

$$r.g. = \frac{cov.g_{12}}{\sqrt{(\sigma^2 g_1)(\sigma^2 g_2)}}$$

where, $cov.g_{1.2}$ is the genetic covariance between two characters, $\sigma^2 g_1$ is the genetic variance of the first character and $\sigma^2 g_2$ is the genetic variance of the second character.

RESULTS AND DISCUSSION

Effect of gamma radiation on the studied traits

Analysis of variance: Data presented in Table 1 show the analysis of variance of the studied traits in M_2 generation. Gamma ray doses caused highly significant variations for all studied traits, except for No. of branches, reflecting the direct effect of the mutagen applied to induce more variations. Therefore, these results indicated to possibility using of this mutagen as a tool to induction more variations for these traits. Thus, it could be establish effective selection programme to improve canola productivity using this mutagen. Differences due to cultivars were highly significant for plant height and significant for the others, with the exception of flowering date. These results indicated that part of the observed variations in all traits except for flowering date was due to the varietal differences. However, for flowering date, all observed variations approximately were due to effect of the used mutagen. On the contrary, the used mutagen was not effect in the trait of No. of branches plant^{-1} where, all recorded differences approximately were due to the varietal differences. The cultivar×dose interaction variance was also highly significant for all studied traits, except for plant height and seed index, where interaction variance was significant and insignificant, respectively. Therefore, these cultivars had differential responses to gamma doses in terms of induction of genetic variations. Thus, the cultivars are playing an important role in success of using this mutagen to induce genetic variations. These results are in agreement with the findings of Emrani *et al.* (2012) for most studied traits.

Genetic variability: Inducing variation in quantitative traits via., mutagenesis can be inferred by the estimation of means ($\bar{X}$), standard deviations (S), coefficients of variation (C.V.) and ranges in the successive M_2 generation of mutagen treated populations. These estimates for the studied quantitative traits after exposure to gamma rays are presented in Tables 2-5.

Gamma radiation induced early flowering variants in both cultivars. Days to flowering were decreased due to mutagen treatments in Serw 4 cultivar while in Serw 6 treatment with 15 Kr produced the earliest plants. The treatment of 15 Kr caused reduction in days to flowering of 25% and 19% in Serw 4 and Serw 6, respectively. Treatment of 5 Kr induced the highest values of standard deviation (S), coefficient of variation (CV) and range of flowering date in Serw 6. In the case of serw 4, the highest values of standard deviation (S) and range were exhibited also by the

Table 1: Mean squares of the studied traits in M_2 generation of two cultivars of canola treated by different gamma radiation doses

		Mean squares						
Source of variation	Degrees of freedom	No. of days to 50% flowering	Plant height (cm)	No. of branches plant^{-1}	No. of pods plant^{-1}	1000-seed weight (g)	Seed yield plant^{-1} (g)	Seed oil content (%)
Replicates	2	4.54	0.85	0.13	24.88	0.02	1.72	0.29
Cultivars (A)	1	57.04	165.22**	2.04*	13207.04*	0.37*	46.07**	7.36*
Error a	2	9.29	1.52	0.04	442.04	0.01	0.17	0.32
G. rays (B)	3	642.71**	211.09**	0.26	15469.15**	0.68**	60.26**	12.20**
a*b	3	19.82**	59.74*	1.49**	20639.93**	0.10	77.74**	7.78**
Error b	12	2.47	16.85	0.25	234.79	0.05	2.11	0.35

* and ** significant at 0.05 and 0.01 probability level, respectively

same treatment with high estimate of Coefficient of Variation (CV) (Table 2). These results indicated that the 5 Kr treatments induced the highest amount of variation in both cultivars. However, the 15 Kr dose could be considered good treatment in serw 4 only where, it produced high values of the estimated variability parameters. Therefore, the doses 5 Kr followed by 15 Kr were the best doses to induce more variations to improve this trait. Decreased number of days to flowering due to gamma radiation was also reported in different crops by Wongpiyasatid *et al.* (1998), Jagadeesan *et al.* (2008) and Emrani *et al.* (2012).

An increase in plant height was detected in serw 4 by 5Kr mutagen dose (Table 2). However, the shortest plants were induced by 15 Kr treatment in Serw 6. Negatively influenced on inducing genetic variability was noticed with all radiation treatments in serw 4. However, in the case of serw 6, treatments of 5 and 15 Kr had positive effective. The 5 Kr dose came in the first for all estimated genetic variability parameters followed by the treatment of 15 Kr. Results indicated that the superiority in the estimated variability parameters by the 5 Kr dose reached to 175.93, 163.89 and 161.9%, respectively. In canola, Emrani *et al.* (2012) reported an increase in plant height by gamma ray treatments. While reduction of plant height with increasing gamma doses was observed by Siddiqui *et al.* (2009). They found that highest amount of variability in this trait was due to the combined treatment 10 Kr gamma rays and 0.75% EMS.

Branches per plant, in general were increased by different gamma radiation treatments in serw 4. In contrast, these treatments decreased number of branches in serw 6 (Table 3). Siddiqui *et al.* (2009) found an increase for primary branches in combined treatments and decreased in separate treatments except 10 Kr. Increasing number of branches by gamma radiation treatments was also reported by Shah *et al.* (1990) and Sorour and Keshta (1994). Approximately, all treatments were produced high estimated variability parameters for branches plant^{-1} compared to their control in both cultivars. The highest values of the estimates were exhibited by 15 and 10 Kr mutagen treatments in serw 4 and 6, respectively.

Table 2: Estimates of means, standard deviations, coefficients of variation and ranges for No. of days to 50% flowering and plant height at M_2 generation of two cultivars of canola treated by different gamma radiation doses

Range	Coefficient of variation (%)	Standard deviation	Mean	Treatment
No. of days to 50% flowering				
99-106	3.43	3.51	102.33^{a}	Serw 4 (control)
87-103	8.42	8.00	95.00^{b}	Serw 4+5 Kr
95-98	1.58	1.53	96.67^{b}	Serw 4+10 Kr
69-84	9.80	7.51	76.67^{d}	Serw 4+15 Kr
96-106	5.29	5.29	100.00^{a}	Serw 6 (control)
92-107	7.61	7.64	100.33^{a}	Serw 6+5 Kr
98-105	3.45	3.51	101.67^{a}	Serw 6+10 Kr
80-82	1.23	1.00	81.00^{c}	Serw 6+15 Kr
Plant height (cm)				
56-126	24.31	22.23	91.44^{bc}	Serw 4 (control)
70-120	15.05	15.27	101.47^{a}	Serw 4+5 Kr
66-107	17.32	14.77	85.27^{c}	Serw 4+10 Kr
66-132	22.85	20.57	90.03^{bc}	Serw 4+15 Kr
65-107	15.54	13.59	87.43^{bc}	Serw 6 (control)
62-130	25.47	23.91	93.87^{b}	Serw 6+5 Kr
75-107	11.94	10.51	88.05^{bc}	Serw 6+10 Kr
60-116	22.31	17.37	77.87^{d}	Serw 6+15 Kr

*Means followed by same letters in the same column are not significantly different at 5% probability

Table 3: Estimates of means, standard deviations, coefficients of variation and ranges for No. of branches plant^{-1} and No. of pods plant^{-1} at M_2 generation of two cultivars of canola treated by different gamma radiation doses

Range	Coefficient of variation (%)	Standard deviation	Mean	Treatment
No. of branches plant^{-1}				
3-5	13.86	0.60	4.33^{c}	Serw 4 (control)
4-6	17.45	0.93	5.33^{ab}	Serw 4+5 Kr
4-6	17.80	0.89	5.00^{bc}	Serw 4+10 Kr
4-7	21.17	1.27	6.00^{a}	Serw 4+15 Kr
4-5	8.80	0.44	5.00^{bc}	Serw 6 (control)
3-5	16.86	0.73	4.33^{c}	Serw 6+5 Kr
4-7	23.98	1.12	4.67^{bc}	Serw 6+10 Kr
3-6	20.09	0.87	4.33^{c}	Serw 6+15 Kr
No. of pods plant^{-1}				
132-180	12.88	15.75	122.33^{e}	Serw 4 (control)
242-373	15.37	43.29	281.67^{b}	Serw 4+5 Kr
188-300	13.32	38.72	290.67^{b}	Serw 4+10 Kr
215-337	11.26	39.27	348.67^{a}	Serw 4+15 Kr
172-250	12.95	28.01	216.33^{c}	Serw 6 (control)
243-349	15.37	43.74	284.67^{b}	Serw 6+5 Kr
127-209	17.98	30.08	167.33^{d}	Serw 6+10 Kr
120-218	16.24	30.43	187.33^{d}	Serw 6+15 Kr

*Means followed by same letters in the same column are not significantly different at 5% probability

An increase in the number of pods plant^{-1} with increasing gamma ray doses in serw 4 was presented in Table 3, where the heaviest pods were induced by 15 Kr treatment. In the case of serw 6, the dose of 5 Kr produced the maximum No. of pods plant^{-1} but such number decreased with the other doses compared to the control. An increase in pods plant^{-1} after gamma ray treatments has also been reported by Shah *et al.* (1990), Sorour and Keshta (1994), Javed *et al.* (2003), Siddiqui *et al.* (2009) and Emrani *et al.* (2012). The mutagen dose 5 Kr produced the best variability in both cultivars. Furthermore, the other doses had high values of variability estimates compared to the control in serw 6. In serw 4, the superiority in standard deviation and range by all doses were higher than the other, where it recorded 274.85, 245.84 and 249.33% and 274.95, 233.33 and 254.17%, respectively. These results indicated to the positive responses in this trait to the used doses of gamma rays as a tool to induction more variations.

In this connection, Thagana *et al.* (2006) reported that, 8 and 10 Kr doses were the best for inducing variability for Karat and Topas varieties and Regent variety, respectively. Gamma radiation treatment negatively influenced 1000 seed weight in both cultivars (Table 4). This result was in agreement with that of Emrani *et al.* (2012). The treatment of 15 Kr of gamma rays was more effective in inducing the highest genetic variability, where it produced the highest values of standard deviation (S), Coefficient of Variation (CV) and range in both cultivars.

Seed yield plant^{-1} was differently affected by radiation treatments, where it increased with all treatments in serw 4 while only with the 5 Kr in serw 6 (Table 4). The highest seed yield was induced by the 15 Kr treatments in Serw 4 (25.42 g). An increase in seed yield plant^{-1} after radiation treatments has also obtained by Shah *et al.* (1999), Javed *et al.* (2003), Siddiqui *et al.* (2009) and Emrani *et al.* (2012). Results of induced genetic variability indicated that positively responsible to mutagen treatments in both cultivars, where all radiation doses were produced higher values of variability parameters compared to their control. The treatment of 15 Kr showed

Table 4: Estimates of means, standard deviations, coefficients of variation and ranges for 1000-seed weight and Seed yield $plant^{-1}$ at M_2 generation of two cultivars of canola treated by different gamma radiation doses

Range	Coefficient of variation (%)	Standard deviation	Mean	Treatment
1000-seed weight (g)				
3.24-3.86	8.17	0.30	3.67^{bc}	Serw 4 (control)
2.94-3.57	8.75	0.28	3.20^{d}	Serw 4+5 Kr
3.25-4.39	14.33	0.52	3.63^{c}	Serw 4+10 Kr
2.45-4.32	22.35	0.80	3.58^{cd}	Serw 4+15 Kr
3.86-4.60	10.19	0.42	4.12^{a}	Serw 6 (control)
2.75-3.39	8.97	0.28	3.12^{d}	Serw 6+5 Kr
3.40-4.47	11.52	0.47	4.08^{ab}	Serw 6+10 Kr
2.82-4.14	16.58	0.62	3.74^{abc}	Serw 6+15 Kr
Seed yield $plant^{-1}$ (g)				
8.98-14.07	15.48	1.69	10.92^{d}	Serw 4 (control)
16.13-26.82	17.85	3.25	18.21^{b}	Serw 4+5 Kr
12.49-21.73	17.63	3.67	20.82^{b}	Serw 4+10 Kr
15.57-25.87	18.41	4.68	25.42^{a}	Serw 4+15 Kr
12.48-18.65	12.10	1.86	15.37^{c}	Serw 6 (control)
16.14-24.71	15.66	3.20	20.43^{b}	Serw 6+5 Kr
10.08-17.95	20.48	2.74	13.38^{cd}	Serw 6+10 Kr
7.69-14.44	13.62	2.06	15.12^{c}	Serw 6+15 Kr

*Means followed by same letters in the same column are not significantly different at 5% probability

Table 5: Estimates of means, standard deviations, coefficients of variation and ranges seed oil content (%) at M_2 generation of two cultivars of canola treated by different gamma radiation doses

Range	Coefficient of variation (%)	Standard deviation	Mean	Treatment
Seed oil content (%)				
38.24-39.67	1.85	0.72	38.90^{b}	Serw 4 (control)
40.17-40.43	0.32	0.13	40.30^{a}	Serw 4+5 Kr
40.91-41.41	0.66	0.27	41.11^{a}	Serw 4+10 Kr
35.97-37.70	2.51	0.93	37.03^{de}	Serw 4+15 Kr
37.08-38.27	1.74	0.66	37.84^{cd}	Serw 6 (control)
35.41-36.83	1.97	0.71	36.12^{e}	Serw 6+5 Kr
40.04-40.64	1.01	0.41	40.64^{a}	Serw 6+10 Kr
37.99-38.63	0.84	0.32	38.31^{bc}	Serw 6+15 Kr

* Means followed by same letters in the same column are not significantly different at 5% probability

the highest values of variability estimates in serw 4, however the 5 Kr dose was the best in serw 6. These results enhanced the possibility of using these doses to induce more variations in this studied trait.

The 10 Kr mutagenic treatment could produce the highest oil content in both cultivars (41.11 and 40.64 %, respectively) (Table 5). This result was consistent with that of Shah *et al.* (1990) and Javed *et al.* (2003). However, this result is in contrast with that of Siddiqui *et al.* (2009), who reported that no treatment could produce oil (%) higher than control. The 15 and 5 Kr doses of gamma rays caused the highest values of standard deviation (S), Coefficient of Variation (CV) and range in serw 4 and 6, respectively. However, negatively responses were observed with the other doses in both cultivars.

Therefore, results of this study provided evidence on the successfulness of used doses of gamma rays as a tool to induce genetic variability in the studied quantitative traits with the aim to improve their performance. In this connection, Siddiqui *et al.* (2009) reported that genetic variability induced through mutation can be utilized successfully for the development of new varieties of rapeseed with improved agronomic traits.

CORRELATION STUDY

Calculated genotypic correlations among the studied traits in M_2 generation of canola as affected by gamma rays are presented in Table 6. The results showed that seed yield appears to have high positive correlation coefficients with each of branches plant^{-1} (0.64), pods plant^{-1} (0.75) and oil content (0.43). While it was weakly positive correlated with all the rest traits, except for plant height which was negatively correlated. These findings indicate that these yield components could be considered the most important contributors in seed yield improvement in canola by gamma rays treatments. Furthermore, strong positive correlation was noticed between branches plant^{-1} and pods plant^{-1} (0.83), reflecting importance of branches plant^{-1} for improvement seed yield plant^{-1} by increasing pods plant^{-1}. However, pods plant^{-1} was negatively correlated with 1000-seed weight (-0.30), where the heaviest pods plant^{-1} might be led to producing seeds with small size. Similar results were emphasized for some of the studied traits by Diepenbrock (2000), Javed *et al.* (2003), Karamzadeh *et al.* (2010) and Emrani *et al.* (2012).

SELECTION OF PROMISING MUTANTS

Mutants for high yielding ability: Sixteen promising high yielding mutants surpassing their parents were isolated from M_2 generation (Table 7). The data obtained indicated that the superiority in seed yield plant^{-1} of these mutants ranged from about 108.15-460.7% in mutants of serw 4 and from 77.29-223.42% in mutants of serw 6.

Earliness mutants: In M_2 generation, selection for early flowering mutants was carried out and seventeen promising mutants were isolated from the population of the irradiated materials by 15 Kr in serw 6, (Table 7). These mutants were earlier in flowering than parent with a range from 7-27 days. Syed *et al.* (2005) isolated an early flowering mutant in mustard line (DLJ-3) treated with 1.0, 1.2 and 1.4 Kr gamma rays. This mutant (MM-1266) also had high seed yielding ability with an increase in oil content over control.

These thirty three promising mutants are need to more of study in advanced generations and will be the backbone of the future breeding programs to improve the economic traits of canola.

Table 6: Genotypic correlation coefficients between studied traits across two cultivars of canola treated by different gamma radiation doses at M_2 generation

Parameter	Plant height (cm)	Branches plant^{-1}	Pods plant^{-1}	1000-seed weight (g)	Seed yield plant^{-1} (g)	Seed oil content (%)
Days to 50% flowering	0.08	0.05	0.35	0.03	0.18	0.10
Plant height (cm)		0.04	0.29	0.03	-0.05	0.23
Branches plant^{-1}			0.83	0.08	0.64	0.34
Pods plant^{-1}				-0.30	0.75	0.03
1000-seed weight (g)					0.19	0.35
Seed yield plant^{-1} (g)						0.43

Table 7: Performance of the isolated promising high yielding and early maturing mutants from M_2 generation of two cultivars of canola treated by different gamma radiation doses

High seed yielding mutants				Early maturing mutants				
Parent/mutant	Seed yield /plant (g)	Superiority (%)	Dose (Kr)	Parent/mutant	Days to flowering (day)	Superiority (%)	Seed yield/ plant (g)	Dose (Kr)
Serw 4 (Parent)	10.92	-	Control	Serw 4 (Parent)	78	-	10.92	Control
Mutant 1	27.17	148.80	10	Mutant 17	51	34.62	4.95	15
Mutant 2	61.23	460.71	15	Mutant 18	61	21.79	5.42	15
Mutant 3	22.73	108.15	15	Mutant 19	60	23.08	9.79	15
Mutant 4	27.43	151.19	15	Mutant 20	53	32.08	5.86	15
Mutant 5	55.05	404.12	5	Mutant 21	51	34.62	5.70	15
Mutant 6	36.13	230.86	5	Mutant 22	58	25.64	5.62	15
Mutant 7	61.23	460.71	15	Mutant 23	56	28.21	4.76	15
Mutant 8	29.58	170.87	15	Mutant 24	71	8.79	8.54	15
Mutant 9	29.71	172.06	15	Mutant 25	56	28.21	9.51	15
Mutant 10	26.82	145.60	5	Mutant 26	56	28.21	3.86	15
Mutant 11	33.65	208.15	10	Mutant 27	56	28.21	2.66	15
Serw 6 (Parent)	15.37	-	Control	Mutant 28	56	28.21	11.70	15
Mutant 12	49.71	223.42	5	Mutant 29	63	19.23	12.46	15
Mutant 13	27.25	77.29	5	Mutant 30	61	21.79	29.58	15
Mutant 14	28.41	84.84	10	Mutant 31	56	28.21	21.38	15
Mutant 15	29.05	89.00	15	Mutant 32	56	28.21	8.03	15
Mutant 16	29.95	94.86	10	Mutant 33	56	28.21	5.86	15

Superiority = [(Mutant performance-parent performance)/Parent performance]×100

CONCLUSION

The present study provided evidence on effectiveness of mutation technique by the 5, 10 and 15 Kr doses of gamma rays as a tool to induce new genetic variability in yield and its components and earliness of the two canola cultivars; serw 4 and 6 and isolation promising mutants with improved performance under the study condition. The highest variation induced was observed due to the treatment of 15 Kr of gamma rays in most studied traits in serw 4 while in 6, 5 Kr dose came in the first rank for most traits. The highest responsible variable to induce genetic variation by radiation treatment is flowering date while the lowest is oil content.

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