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Improvement of restorer and maintainer lines in rice (*Oryza sativa* L.) by gamma radiation

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ABSTRACT

Rice is a strictly self-pollinating crop. However, in hybrid rice seed production, an effective male sterility system is used to produce hybrid seed in bulk. In a hybrid rice system, the pollen grains of cytoplasmic male sterile (CMS) lines are sterile, and the female organ of the CMS depends on the fertile pollen released by the maintainer or restorer lines via out-crossing or cross-pollination to produce seeds. Floral traits and growth behavior of CMS and its corresponding maintainer and restorer lines are essential factors in hybrid rice seed production because they influence outcrossing or cross-pollination. Seeds of the 4 maintainer lines, or B lines, and the 5 restorer lines were treated with five gamma radiation doses: 0, 100, 200, 300, and 400 Gy, to study their mutagenic effect on the growth, yield, and floral traits of these rice genotypes, as well as to induce genetic variability for selecting plants with desirable characters. Results showed that all growth, yield, and floral traits studied in the M1 generation decreased steadily with increasing doses of gamma rays when compared to the control. The dose of 300 Gy recorded the highest mean values for some growth, yield, and floral traits studied in the M2 generation when compared to the control. The genotype-dose interaction was significant and highly significant for all growth, yield, and floral traits studied in M1 and M2 segregating generations except for anther width in the M1 generation, which indicated that the tested genotypes varied from treatment to treatment. The highest values for growth and yield traits were recorded when using Giza 178, Giza 182, and the IR 58025B mutant with 300 Gy of gamma rays in the M2 segregating generation. And the highest values for floral traits were recorded when using Giza 182 and the IR 70368B mutant with 300 Gy of gamma rays in the M2 segregating generation. The measurements of variation were, in general, higher in the treated plants at M2 generation. High heritability coupled with high genetic advance as percent of the mean was recorded for most studied traits, suggesting the improvement of these characters through simple phenotypic selection. Used irradiation by gamma-ray exhibited different genetic variability for the development of restorer and maintainer lines, such as desirable plant height, early heading, and high yield plants. Also, improving floral traits such as the length and width of anthers, percentage of pollen fertility, number of pollen grains per anther, total stigma length, and stigma width

Keywords: Restorer lines, maintainer lines, floral traits, gamma irradiation, genetic parameters, mutations

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops in the world because it provides food for more than 3.5 billion people (Khush, 2013). Rice yield is required to increase at least 1% annually to meet the growing global rice demand which results from population growth, economic development, and the threat of environmental pressures (Fageria, 2007 and Normile, 2008). To achieve this goal, breeding new rice varieties with higher yield potential is the major strategy to improve on-farm yield (Foley *et al.,* 2011). Over the past decades, rice yield potential had been much improved with the symbolic development of semi-dwarf varieties in 1950s, hybrid varieties in 1970s, and super hybrid varieties in 1990s (Peng *et al.,* 1999; Cheng *et al.,* 2007). The development and use of hybrid rice varieties on commercial scale utilizing male sterility and fertility restoration system has proved to be one of the milestones in the history of rice improvement.

The development of hybrid rice is a promising way of increasing yield even more, resulting in food security and poverty reduction. In China, hybrid rice was shown to give 15-20% higher yield than ordinary pure lines in a farmer's fields. The development of hybrid rice is facilitated using a male sterile line. The first set of cytoplasmic male sterility (CMS, or three-line) systems was produced in 1970, while the first hybrid rice was released in 1974, outyielding, on average, the conventional rice varieties by 20% (Guohui and Longping, 2003). The three-line system requires a cytoplasmic male sterile (A line), a maintainer (B line) and a restorer (R line) to produce F_1 seeds (Jiming*et al.,* 2009). Hybrid rice has an advantage not only in yield but also in combining resistance to diseases and pests found in the parents. Moreover, hybrid rice possesses another important characteristic, adaptability to various environmental constraints, especially drought (Virmani, 1996).

Mutation breeding is one of the most effective ways of inducing substantial genetic variability in plant species with desirable traits in the new mutant lines (Mei *et al.,* 2007). Mutation has been successfully employed in breeding of several food crop varieties, autogamous plants and export crops. In plant improvement, the irradiation of seeds may cause genetic variability that enable plant breeders to select new genotypes with improved characteristics e.g., large number of semi-dwarf, earliness, tillering ability, grain yield, quality and resistance to biotic and abiotic stresses (Ashraf *et al.,* 2003, Soomro *et al.,* 2006 and Bibi *et al.,* 2009), suggesting that it is also an important technique to complement the conventional breeding method. Therefore, there is a need to pay immediate attention for raising present yield ceiling in varieties, through mutation breeding, which is widely adopted besides possessing good grain quality characteristics.

Also, more work needs to be done to identify new restorer lines (R lines) that can contribute to heterosis and greater yield when crossed with the male sterile lines. The success of a hybrid is dependent on the level of heterosis that can be expressed after crossing the parental varieties. Combining different varieties is the first step to obtaining heterosis, but its expression improves as combinations between varieties belonging to different groups (*indica* and *japonica*) are explored (Guimaraes, 2009). An alternative that can be used to develop hybrids with higher potential might be the use of yield-enhancing genes from other species (Longping, 2003). In the 1980s, the use of different sources derived from induced mutations was a popular choice to generate genetic diversity for specific traits in rice, and today the technique has become part of the toolkit breeders use to enhance specific rice characteristics in well-adapted varieties, with the most popular mutagen still being gamma rays (Guimaraes, 2009). However, commercial hybrid rice varieties can be used as a source of genetic material to produce better A and R lines. Also, mutation induction through gamma irradiation is one way to create greater genetic diversity among male sterile lines before backcrossing them and testing the general combining ability of the F1 generation.

Therefore, the objective of this study was to improve various quantitative and floral traits for restorer and maintainer lines with gamma irradiation for better hybrid rice seed production. In addition to estimating genetic parameters that enhancement selection desirable mutations.

MATERIAL AND METHODS

Plant material:

The present investigation was conducted at the Rice Research and Training Center, Sakha Agricultural Research Station, KafrElsheikh Governorate, Egypt, (Lat/Long: 31°08'N/30°58'E) in two consecutive summer rice growing seasons 2021 and 2022. Nine rice genotypes (5 restorer lines and 4 maintainer lines) were used to induce mutations with gamma irradiation to improve hybrid rice seed production. Names, origin, and characteristics of these genotypes are presented in Table (1).

Table 1. Name, characteristics and origin of the restorer lines and maintainer lines of the rice varieties utilized in the current study.

No.	Genotypes		Days to 50% heading	Origin
1	**Giza 178**	Restorers	105 day	Egypt
2	**Giza 179**		93 day	Egypt
3	**Giza 181**		115 day	Egypt
4	**Giza 182**		97 day	Egypt
5	**GZ 9399**		94 day	Egypt
6	**IR 69625B**	Maintainers	105 day	IRRI
7	**G 46B**		89 day	China
8	**IR 58025B**		108 day	IRRI
9	**IR 70368B**		104 day	IRRI

Mutagen treatment:

Around 750 well-filled seeds of uniform size from each restorer or maintainer line of rice with a moisture content of 12% were packed in butter paper covers and placed in an irradiation chamber located in a vertical drawer inside the lead flask. In the gamma chamber at the National Centre for Radiation Research and Technology in Nasr City, Cairo, Egypt, seeds were exposed to gamma rays from the Cobalt 60 (Co60) gamma source at the right time for each dose based on the half-life of the source. Non-irradiated (0 Gy) dry seeds were taken as controls. The seeds of five restorer lines and four maintainer lines were irradiated at four different doses, starting from 100 Gy to 400 Gy with an interval of 100 Gy. The irradiated seeds were sown on the same day in a nursery established at the experimental farm of Sakha Agricultural Research Station, Kafr Elsheikh, Egypt.

M_1 and M_2 generations:

In 2021 season, M_1 seeds that had been exposed to 0 Gy, 100 Gy, 200 Gy, 300 Gy and 400 Gy gamma radiation were sprouted and transplanted singly (one plant per hill), when the seedlings were aged thirty-day-old in puddled field following seven rows plot with row length was 3.0 m. Row to row and plant to plant distances 20 cm and 20 cm were kept, respectively.

To avoid out-crossing, first three panicles in each of the 50 randomly selected plants in each treatment were bagged at the time of panicles emergence. At the time of maturity, the seeds were harvested from three bagged tillers, as well as unbagged tillers, separately from each individual plant.

In 2022 season, the M_1 plants that survived up to maturity were harvested and kept separately to grow in M_2 generation from each gamma radiation treatment. In M_2 generation, seedlings were raised from the seeds of the survived plants in M_1 generation.

The experiment was designed using a two-factorial (rice varieties and doses of gamma ray irradiation) randomized complete block design (RCBD) with three replications in two rice growing seasons to raise the M1 and M2 generations for evaluating the genetic effects of mutagenic treatments. Recommended doses of fertilizer and agricultural practices were carried out to assure a good stand and a healthy crop. Weeds were chemically controlled by applying two liters of S-4-chlorobenzyl diethylthiocarbamate (Saturn or Feddan) four days after transplanting.

Viable mutations in M_2 progeny were examined periodically through the entire growth period for visible mutations affecting various morphological attributes. To study the magnitude and nature of induced polygenic variability in M_2 generation, observations on various quantitative traits were recorded on all the plants in each treatment. The following observations were recorded:

Two types of traits were scored in this study:

1) Growth and yield traits:

The following laboratory experiment were measured on each genotype at each dose of irradiation; germination percentage was counted the number of seeds germinated at each dose of irradiation manually by sowing 50 seeds in Petri dishes on moist filter papers. The percentage of germination was calculated using the formula:

$$\text{Germination percentage (\%)} = \frac{\text{Amount of germinal seeds}}{\text{Amount of sowing seeds}} \times 100$$

The following morphological attributes were measured on each treated; days to 50% flowering (days) was calculated as the average between numbers of days from sowing to the first panicle exertion and number of days from sowing to the last panicle emergence; plant height (cm) was measured from the soil surface to the tip of the main panicle at maturity; number of panicles per plant was determined by counting the number of panicles per plant at the ripening stage; panicle length in cm (the main panicle of each plant was measured from the base to the tip of the panicle excluding owns at complete maturity); filled grains panicle^{-1} and seed set percentage (%) was calculated for each panicle (number of florets with swelled ovary/number of total florets × 100), and the average of the panicles in a pot was used as the replicate percentage of seed set, and grain yield per plant (g) was recorded as the weight of the individual plant grain yield and adjusted to 14% moisture content.

2) Floral traits:

Floral traits observations were recorded on thirty randomly selected spikelets from all the genotypes at each dose of gamma irradiation. Spikelets samples were immediately fixed in acetic-alcohol (acetic acid: ethanol = 1:3) and kept in the fridge at four degrees until investigation, according to protocol by (Jagadish*et al.* 2010). Floral traits viz., pollen fertility (%), anther length (mm), anther width (mm), basal pore length (µm), number of pollen grains per anther, pistil length (Total stigma length) (mm), stigma non-brush-shaped part SNBP (mm), and stigma width (mm) were measured under ocular microscope at 10x magnification to eyepiece micrometer and images were taken with DP70 digital camera attached to an Axioplane 2 microscope (Carl Zeiss, Germany) at 350 for floral traits.

Pollen fertility: Pollen fertility or sterility was estimated by using a 1% iodine potassium iodide (I-KI2) solution (Prasad et al. 2006). Anthers were collected from three randomly chosen spikelets (top, middle, and bottom), and pollen grains were tweezed out of the anther on a glass slide. The fertile (fully stained) and sterile pollen grains (unstained) were counted in three microscopic fields under a light microscope. Pollen fertility was calculated and expressed in percentage as follows:

$$\text{Pollen fertility (\%)} = \frac{\text{Total number of well-stained pollens.}}{\text{Total number of stained and unstained pollens}} \times 100$$

Number of pollen grains per anther: Number of pollen grains per anther is estimated using the formula given by (Suzuki 1981).

Number of pollen grains per anther (V) = -1172 +1277 x Anther length

Statistical analysis:

Experimental data were subjected to a two-way analysis of variance (two-way ANOVA, Model: Yijk = m + Gi + Bk + Aj + GAij + Eijk) with Dunnett's post test at a 5% level of probability to determine the differences in the average of all tested parameters between genotypes and gamma irradiation treatments. Statistical analysis was performed using the "COSTAT" computer software package as described by Gomez and Gomez (1984). For calculating genetic parameters, the data of each character for all rice genotypes in the M1 segregating generation were analyzed separately by the analysis of variance according to the formula suggested by Burton (1952a) and Hanson et al. (1956) as follows:

$$\text{Genetic variance (GV)} = \frac{M_1 - M_2}{r}$$

$$\text{Phenotypic variance (PV)} = GV + M_2$$

$$\text{Genetic coefficient of variance (GCV \%)} = \frac{\sqrt{GV}}{\bar{X}} \times 100$$

$$\text{Phenotypic coefficient of variance (PCV \%)} = \frac{\sqrt{PV}}{\bar{X}} \times 100$$

$$\text{Heritability in broad sense (Hb \%)} = \frac{GV}{PV} \times 100$$ (Hanson *et al.,* 1956)

$$\text{Genetic advance upon selection (Gs)} = K * \sqrt{PV * Hb}$$ (Johnson *et al.,* 1955)

$$Gs\ \% = \frac{Gs}{\bar{X}} \times 100$$ (Miller *et al.,* 1958)

Where,

M_1 = Mean squares due to genotypes.

M_2 = Mean squares due to error.

r = Number of replications.

$\bar{X}$ = Mean value of genotypes.

Where, K is the selection differential and equals 2.06 at selection intensity of 5 %, (Hanson *et al.* 1956).

RESULTS

1. Growth and yield traits of the mutant line:

1.1. Analysis of variance:

The analysis of variance for some growth and yield traits scored in this study is presented in Table (2). The differences among replications were non-significant for all growth and yield traits. While highly significant differences were observed for plant height (cm) in M_2 generation and for grain yield per plant (g) in M_1 and M_2 generations. Analysis of variance revealed highly genetic variation was observed among all genotypes for all growth and yield traits in M_1 and M_2 generations. The differences among treatments were highly significant for all growth and yield traits. The genotype × dose interactions were significant for all growth and yield traits in M_1 and M_2 generations.

Table 2. Observed mean squares for some growth and yield traits of rice genotypes mutant in M_1 and M_2 generations.

Source of variance	df	Germination percentage (%)		Days to 50% flowering (days)		Plant height (cm)		Number of panicles plant^{-1}	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Replications	**2**	2.08ns	0.58ns	0.13ns	0.05ns	0.25ns	10.50**	0.14ns	0.14ns
Genotypes (G)	**8**	130.93**	43.45**	1110.04**	1154.34**	944.25**	454.45**	55.02**	42.76**
Doses (D)	**4**	23391.72**	74.17**	17.11**	22.87**	845.06**	551.87**	104.42**	113.09**
G x D	**32**	40.67**	3.72**	1.06**	1.92**	13.56**	28.50**	2.62**	1.99**
Error	**88**	1.39	0.37	0.42	0.36	0.79	1.27	0.47	0.38
Total	**134**	-	-	-	-	-	-	-	-

Table 2: Continued.

Source of variance	df	Panicle length (cm)		Filled grains panicle^{-1}		Seed set percentage (%)		Grain yield per plant (g)	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Replications	**2**	0.03ns	0.36ns	0.68ns	3.53ns	0.33ns	0.11ns	0.08**	0.65*
Genotypes (G)	**8**	3.70**	4.82**	312.59**	177.46**	68.23**	6.03**	6.93**	10.48**
Doses (D)	**4**	217.67**	93.12**	93413.12**	7071.88**	29809.25**	1859.63**	1482.07**	440.52**
G x D	**32**	0.53**	0.59**	174.27**	17.07**	124.49**	3.92**	0.45**	0.39**
Error	**88**	0.23	0.29	7.51	1.23	4.53	0.51	0.02**	0.17
Total	**134**	-	-	-	-	-	-	-	-

1.2. Effect of mutagens on the mean performance of growth and yield traits in M_1 and M_2 generations:

The effect of gamma irradiation on restorers and maintainers of rice was studied in M1 and M2 generations under field conditions. The mean performances in respect of various growth and yield characters in M1 and M2 segregating populations are presented in Table 3. Concerning the gamma irradiation doses, Table 3 shows that the high dose irradiation caused severe damage to the cell, as the percentage of germination, filled grain panicle^{-1}, and seed set percentage decreased when compared to control in M1 and M2 generations. While the dose of gamma irradiation of 300 Gy gave the highest values for plant height, number of panicles in hill 1, panicle length, and grain yield per plant (123.41), (20.96), (22.86), and (49.83) in the M2 segregating population, respectively. The maximum reduction was observed at higher concentrations of the mutagens (400 Gy).

With respect to genotypes as shown in Table (3), Giza 178 gave the highest mean values for germination percentage (70.62 and 95.88) in M_1 and M_2 segregating generations, respectively. Likewise, the genotypes IR 58025B gave the highest mean values for days to 50% flowering, plant height, number of panicles per hill, panicle length, seed set percentage and grain yield per plant ((111.53 and 113.41 day); (113.60 and 123.47 cm); (19.11 and 21.01); (18.68 and 21.80 cm); (60.23 and 85.18 %) and (36.74 and 47.08 g)) in M_1 and M_2 segregating generations, respectively. And also the genotypes Giza 182 gave the highest mean values for filledgrains panicle^{-1} and grain yield per plant (169.69) and (46.85) in M_2 generations, respectively. There was a gradual decrease for all growth indicators plant height, days to heading and panicle length with the increase of radiation dose (Labrada *et al.* 2001).

Table 3. Mean of performance for some growth and yield traits of rice genotypes mutations in M_1 and M_2 generations.

Treatment	Germination percentage (%)		Days to 50% flowering (days)		Plant height (cm)		Number of panicles plant^{-1}	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Doses (Gy)								
Cont.	94.24a	94.71a	100.96a	103.18a	111.44a	111.89e	17.82a	17.30c
100	86.81b	93.68b	100.19b	101.52b	106.85b	114.74d	14.69c	16.85d
200	77.38c	93.31c	99.56c	101.40b	102.07c	120.26b	15.82b	18.1b
300	59.83d	92.05d	98.89d	100.74c	97.48e	123.41a	17.92a	20.96a
400	20.37e	90.41e	99.42c	101.27b	99.95d	117.11c	14.13d	15.45e
Genotype								
Giza 178	70.62a	95.88a	96.67e	97.41e	96.78f	111.13f	16.66c	18.11c
Giza 179	67.93d	94.13b	109.13b	111.31b	101.07d	118.20d	14.41f	16.13e
Giza 181	68.93c	93.33c	94.07f	96.07f	90.67g	107.87g	15.60d	17.31d
Giza 182	70.85a	91.47d	94.00f	96.01f	99.73e	115.53e	15.10e	16.55e
GZ 9399	67.67d	90.20e	94.00f	95.74f	99.13e	115.20e	13.77g	15.51f
IR 69625B	66.07e	93.07c	106.76c	109.03c	107.60c	120.47c	17.32b	18.99b
G 46B	61.40f	93.13c	86.53g	88.21g	111.47b	121.93b	17.17b	18.75b
IR 58025B	69.93b	91.13d	111.53a	113.41a	113.60a	123.47a	19.11a	21.01a
IR 70368B	66.13e	93.13c	105.53d	107.41d	112.00b	123.53a	15.54de	17.23d

Table 3: Continued.

Treatment	Panicle length (cm)		Filled grains panicle^{-1}		Seed set percentage (%)		Grain yield per plant (g)	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Doses (Gy)								
Cont.	22.36a	22.05b	181.28a	180.63a	93.50a	93.17a	47.97a	48.01b
100	16.51d	20.32d	80.49c	164.52d	67.87c	83.99d	33.20c	45.30d
200	16.99c	21.06c	68.35d	166.50c	36.95d	84.96c	32.73d	47.05c
300	18.1b	22.86a	97.55b	176.20b	77.63b	88.46b	36.75b	49.83a
400	14.79e	18.02e	20.06e	139.00e	10.75e	70.92e	28.43e	39.29e
Genotype								
Giza 178	17.22c	20.11d	94.66ab	167.43c	58.35b	83.95cd	35.85e	46.01c
Giza 179	17.99b	21.33b	88.41ef	168.49b	53.67e	83.95cd	36.37c	46.49b
Giza 181	17.27c	20.27cd	86.6fg	158.56g	55.91d	83.85d	35.95d	46.03c
Giza 182	18.05b	21.21b	91.25cd	169.69a	56.49cd	84.46bc	36.62b	46.85a
GZ 9399	17.32c	20.39cd	95.55a	163.73ef	58.03bc	85.18a	34.69h	44.48e
IR 69625B	17.93b	21.13b	92.8bc	164.06e	60.18a	84.52b	35.41f	45.44d
G 46B	17.31c	20.51c	86.11g	165.35d	57.33bcd	83.23e	35.29g	45.22d
IR 58025B	18.68a	21.80a	89.32de	167.87bc	60.23a	85.18a	36.74a	47.08a
IR 70368B	17.98b	21.01b	81.23h	163.13f	55.85d	84.40bc	35.42f	45.45d

1.3. Effects of interaction between genotypes and gamma irradiation doses:

The results in (Table 4) indicated that the interaction between the rice genotypes and gamma rays treatments on growth and yield traits had a highly significant effect on all this traits at M_1 and M_2 segregating generations.

M_1 generation:

Germination percentage (Table 4) was gradually decreased with increasing doses of gamma rays compared with control for all rice genotypes studied at M_1 generation. Giza 178 gave the highest germination percentage (95.12 %) with control treatment. On the other hand, the lowest germination percentage values for the genotype G 46B (13.67 %) with (400 Gy) dose treatment. These results indicated that the effectiveness of gamma rays was found with the increase of the doses with either plus or minus effect. Similar observations were also observed by (Harding *et al.,* 2012; Ramchander, 2015) for gamma rays.

With respect to days to 50% flowering, does not follow a linear relationship with all studied rice genotypes. Days to 50% flowering was slightly decreased (one or five days) in gamma radiation treatments (100 Gy, 200 Gy, 300 Gy and 400 Gy) over the control in rice genotypes at M_1 generation. Maturity was early for the genotype G 46B (85.33 day) at 300 Gy in M_1 segregating generation, whereas heading was delayed in the genotype IR 58025B (112.67 day) at the control in M_1 generations. These results were in close agreement with the results obtained by (Kumar, 2005; Do *et al.,* 2006).

The present study exhibited that (Table 4) the plant height at maturity were decreased with the proportion of increase in dose in all the treatments of gamma rays in all rice genotypes studied in M_1 generation when compared to control. In addition to the most desirable values towards medium height for plant height were obtained from the all rice genotypes studied at dose of gamma irradiation 100 Gy in M_1 generation. While the number of panicles per hill, panicle length, total grains panicle^{-1} and grain yield per plant were increased with the proportion of increase in dose in all the treatments of gamma rays in all rice genotypes studied in M_1 generation when compared to control.

The highest significant increase in number of panicles per plant (21.55 panicle) was recorded for the genotype IR 58025B at 300 Gy treatment in M_1 generation when compared to control. The highest significant increase for panicle length (23.75 cm), filled grains panicle^{-1} (180.27), seed set percentage (95.72 %) and grain yield per plant (48.94 g) were recorded for the genotype IR 58025B at control and followed by dose of gamma irradiation 300 Gy in M_1 generation. These results indicated that the effectiveness of gamma rays was found with the increase of the doses with either plus or minus effect. Furthermore, the results revealed that the varieties responded differently. These results were in close agreement with (Gomma *et al.,* 1995).

M_2 generation:

Germination percentage (Table 4) was gradually decreased with increasing dose of gamma rays when compared to control for all rice genotypes studied at M_2 generation. Giza 178 gave the highest germination percentage (97.42%) with control treatment. On the other hand, the lowest germination percentage value were obtained from the genotype GZ 9399 (85.33%) in M_2 segregating generation at (400 Gy) treatment. These results indicated that the effectiveness of gamma rays was found with the increase of the doses with either plus or minus effect. Furthermore, the results revealed that the varieties responded differently. This shows significant influence of mutagen on germination. Similar observations were also observed by (Harding *et al.,* 2012; Ramchander, 2015) for gamma rays.

Concerning days to 50% flowering does not follow a linear relationship between doses in all rice genotypes studied. Days to 50% flowering was slightly decreased (one or five days) in gamma radiation treatments of 100 Gy, 200 Gy, 300 Gy and 400 Gy over the control in rice genotypes at M_2 generation. Maturity was early for the genotype G 46B (87.34 day) at dose of gamma irradiation 300 Gy in M_2 segregating generation, whereas heading was delayed in the genotype IR 58025B (114.68 day) at the control in M_2 segregating generations. These results were in close agreement with the results obtained by (Kumar, 2005; Do *et al.,* 2006).

Table 4. The interaction between rice genotypes and gamma irradiation doses effected on some growth and yield traits in M_1 and M_2 generations.

Genotypes	Doses (Gy)	Germination percentage (%)		Days to 50% flowering (days)		Plant height (cm)		Number of panicles per plant	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Giza 178	Cont.	95.12a	97.42a	99.33k	101.69k	104.00lm	106.33v	17.86ef	17.33j-m
	100	89.67d	95.15bcd	97.33l	97.00l	97.00op	109.67tu	14.85m-p	15.92o-r
	200	79.67hij	95.77b	96.33lm	96.89l	95.33qr	112.33qr	16.60g-j	18.90fg
	300	62.67mn	95.41bc	95.00no	95.56mno	92.33t	117.00jkl	19.22cd	22.34c
	400	26.00s	95.67b	95.33mn	95.89l-o	95.21qr	110.33st	14.75m-q	16.06opq
Giza 179	Cont.	95.33a	95.67b	110.67bcd	114.18ab	115.00c	113.33pqr	16.69g-j	16.33nop
	100	91.00cd	94.67b-e	110.00de	111.33e	105.00kl	114.67m-p	13.39stu	15.92o-r
	200	76.33k	94.33c-f	108.33fg	110.34efg	96.67opq	117.67ijk	14.56n-r	16.80l-o
	300	60.00op	93.67e-h	107.67g	109.68g	93.33st	125.00ef	15.43k-n	18.31f-j
	400	17.00v	92.33ijk	109.00ef	111.01ef	95.33qr	120.33h	11.95v	13.30u
Giza 181	Cont.	93.67ab	94.67b-e	94.67nop	96.68lm	97.33o	98.67x	18.25de	17.67h-l
	100	86.33e	94.67b-e	94.33n-q	96.33lmn	96.67opq	103.33w	13.98pqrs	16.52m-p
	200	81.67fgh	93.33f-i	94.33n-q	96.34lmn	90.67u	107.67v	15.14l-o	17.40i-m
	300	63.67mn	92.67hij	93.67pqr	95.68mno	85.33v	115.33l-p	17.18fgh	20.17de
	400	19.33u	91.33kl	93.33qr	95.34no	83.33w	114.33nop	13.48stu	14.81st
Giza 182	Cont.	95.45a	94.67b-e	95.00no	97.01l	106.00jk	108.00uv	18.25de	17.67h-l
	100	91.00cd	91.00l	94.33n-q	96.33lmn	103.33m	111.67rs	14.27o-s	15.62p-s
	200	83.45f	92.67hij	94.00o-r	96.01l-o	97.67o	119.00hij	14.27o-s	16.50m-p
	300	60.33op	90.67lm	93.00r	95.01o	95.00qr	123.00g	16.01i-l	18.93fg
	400	24.00t	88.33n	93.67pqr	95.68mno	96.67opq	116k-o	12.72tuv	14.06tu
GZ 9399	Cont.	95.23a	94.00d-g	95.00no	97.01l	109.00gh	110.33st	15.53k-n	15.33qrs
	100	86.00e	93.00ghi	94.67nop	95.33no	104.00lm	114.00opq	12.52uv	15.02rst
	200	77.67jk	91.67jkl	93.67pqr	95.68mno	95.67pqr	117.33jkl	13.69rst	15.90o-r
	300	58.45p	87.00o	93.00r	95.01o	92.67t	119.67hi	15.14l-o	18.00g-k
	400	21.00u	85.33p	93.67pqr	95.68mno	94.33rs	114.67m-p	11.95v	13.30u
IR 69625B	Cont.	93.67ab	94.33c-f	108.00fg	110.01fg	115.00c	116.33k-n	19.03cd	18.33fghi
	100	83.00f	93.67e-h	106.00i	109.33gh	110.00fg	114.67m-p	16.01i-l	18.32fg-j
	200	74.00l	93.33f-i	106.33hi	108.34hi	106.00jk	125.67de	16.89f-i	19.20ef
	300	64.67m	92.67hij	107.33gh	109.34gh	100.00n	129.00bc	18.93cd	22.03c
	400	15.00vw	91.33kl	106.12i	108.13i	107.00ij	116.67klm	15.77j-m	17.07k-n
G 46B	Cont.	93.00bc	94.33c-f	87.00s	89.01p	118.33b	116.67klm	18.25de	17.67h-l
	100	82.33fg	94.67b-e	87.33s	87.67qr	113.33d	119.67hi	15.14l-o	16.82l-o
	200	64.67m	93.67e-h	86.33st	88.34pqr	111.00ef	125.67de	16.31h-k	18.60fgh
	300	53.33q	93.33f-i	85.33t	87.34r	106.33jk	129.33b	20.38b	23.59b
	400	13.67w	89.67m	86.67s	88.68pq	108.33hi	121.33gh	15.77j-m	17.07k-n
IR 58025B	Cont.	92.33bc	92.67hij	112.67a	114.68a	121.00a	119.67hi	19.41bc	18.67fg
	100	83.00f	92.33ijk	111.67ab	113.00cd	117.00b	125.00ef	17.76ef	21.02d
	200	80.33ghi	91.67jkl	111.33bc	113.34bcd	114.00cd	129.67b	19.80bc	22.20c
	300	62.00no	90.67lm	110.33cd	112.34d	106.00jk	120.33h	21.55a	24.83a
	400	32.00r	88.33n	111.67ab	113.68abc	110.00fg	119.67hi	17.04f-i	18.32fg-j
IR 70368B	Cont.	94.33ab	94.67b-e	106.33hi	108.34hi	117.33b	117.67ijk	17.08fgh	16.67mno
	100	89.00d	94.00d-g	106.00i	107.33ij	115.33c	120.00h	14.27o-s	16.52m-p
	200	78.67ij	93.33f-i	105.33ij	107.34ij	111.67e	127.33cd	15.14l-o	17.40i-m
	300	53.33q	92.33ijk	104.67j	106.68j	106.33jk	132.00a	17.47efg	20.48d
	400	15.33vw	91.33kl	105.33ij	107.34ij	109.33gh	120.67h	13.73q-t	15.06rs

Table 4: Continued.

Genotypes	Doses (Gy)	Panicle length (cm)		Filled grains panicle^{-1}		Seed set percentage (%)		Grain yield per plant (g)	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Giza 178	Cont.	21.62cd	21.33fgh	181.28ab	181.00c	92.10abc	92.04cd	47.69b	47.99hij
	100	15.76k-n	18.62k	77.74fgh	160.68o	65.17ghi	82.78o	33.25g-k	45.36st
	200	16.20j-m	20.21ij	78.62e-h	170.10hi	41.67jk	85.21j-n	32.82h-l	47.18klm
	300	17.94e-h	22.59bcd	113.56c	181.55bc	80.57a-g	88.99ef	36.90de	50.01bc
	400	14.59no	17.79kl	22.12k	143.82q	12.27lmn	70.74rs	28.59mn	39.50xyz
Giza 179	Cont.	22.68abc	22.35cde	189.35a	187.00a	92.21abc	91.22d	49.14a	48.84efg
	100	16.26i-l	21.02ghi	79.78e-h	165.78kl	66.04f-i	82.15op	33.73ghi	46.00p-s
	200	17.21g-j	21.32fgh	69.01hij	170.40hi	37.43jk	85.12j-n	33.13g-k	47.61jkl
	300	18.71e	23.60a	82.53d-h	178.44d	61.46hi	89.33e	37.18de	50.38b
	400	15.07mno	18.34k	21.36k	140.81r	11.21lmn	71.93q	28.69mn	39.64xy
Giza 181	Cont.	21.98bc	21.69efg	165.82b	169.00ij	92.80abc	92.52bc	48.92a	49.05def
	100	16.51ijk	20.12j	86.19d-h	157.07p	64.38ghi	84.65mn	33.28g-j	45.41st
	200	16.46i-l	20.42ij	76.58ghi	158.40p	40.95jk	82.93o	32.70i-l	47.01lmn
	300	17.42f-i	22.05def	85.60d-h	172.55fg	71.35e-h	88.04fgh	36.62ef	49.66cd
	400	13.99o	17.08l	18.82k	135.79t	10.06mn	71.1qrs	28.22mn	39.01yz
Giza 182	Cont.	23.04ab	22.69bcd	186.67ab	187.00a	93.24abc	93.50b	49.85a	49.98bc
	100	16.76h-k	20.72hij	82.11d-h	170.29hi	65.98f-i	84.27n	33.91gh	46.23o-r
	200	17.21g-j	21.32fgh	69.59hi	171.30gh	36.95jk	85.24j-n	33.30g-j	47.84ijk
	300	18.19efg	22.98abc	99.58cde	179.06d	76.99b-h	89.24e	37.29de	50.51ab
	400	15.07mno	18.34k	18.31k	140.81r	9.29mn	70.06st	28.74mn	39.70x
GZ 9399	Cont.	21.98bc	21.69efg	176.55ab	179.00d	95.47a	95.72a	46.08c	45.91qrs
	100	16.26i-l	20.12j	93.46c-g	165.18lm	49.19ij	85.79j-m	32.16kl	43.92v
	200	16.96hij	21.02ghi	78.8e-h	164.70lmn	42.59jk	85.05k-n	31.78l	45.74rs
	300	17.42f-i	22.05def	108.86c	173.48ef	91.72a-d	88.21e-h	35.74f	48.52fgh
	400	13.99o	17.08l	20.07k	136.29t	11.15lmn	71.11qrs	27.68n	38.29A
IR 69625B	Cont.	22.68abc	22.35cde	188.68a	177.67d	93.46abc	93.51b	47.09bc	47.24klm
	100	16.26i-l	20.42ij	80.66e-h	166.38kl	73.76d-h	84.86lmn	32.84h-l	44.82tu
	200	16.96hij	21.02ghi	72.50ghi	163.80mn	40.20jk	84.43n	32.43jkl	46.64m-p
	300	18.45ef	23.29ab	103.07cd	173.17ef	83.42a-f	88.35e-h	36.46ef	49.45cde
	400	15.28lmn	18.59k	19.07k	139.30rs	10.08mn	71.44qr	28.25mn	39.05xyz
G 46B	Cont.	20.49d	20.29ij	185.32ab	183.00b	92.55abc	91.50cd	46.92bc	46.74mno
	100	16.26i-l	20.42ij	74.83ghi	164.88lmn	81.14a-g	81.13p	32.72i-l	44.67u
	200	16.96hij	21.02ghi	56.19ij	165.90kl	29.17kl	84.36n	32.32jkl	46.49n-q
	300	17.94e-h	22.67bcd	98.41c-f	174.41e	75.45c-h	87.35hi	36.34ef	49.29de
	400	14.89no	18.13k	15.77k	138.55s	8.35n	71.80qr	28.15n	38.92zA
IR 58025B	Cont.	23.75a	23.35ab	180.27ab	183.00b	95.72a	95.15a	48.94a	49.07def
	100	17.76e-h	21.32fgh	74.25ghi	167.29jk	72.39e-h	85.9jkl	34.08g	46.47n-q
	200	17.71e-h	21.92def	66.1hij	169.20i	36.52jk	86.05jk	33.63ghi	48.29ghi
	300	18.87e	23.80a	103.07cd	179.06d	84.38a-e	87.78gh	37.79d	51.16a
	400	15.28lmn	18.59k	22.89k	140.81r	12.13lmn	71.00qrs	29.28m	40.43w
IR 70368B	Cont.	23.04ab	22.69bcd	177.58ab	179.00d	93.93ab	93.39b	47.09bc	47.25klm
	100	16.76h-k	20.12j	75.41ghi	163.08n	72.74e-h	84.41n	32.84h-l	44.83tu
	200	17.21g-j	21.32fgh	47.75j	164.70lmn	27.08klm	86.23ij	32.44jkl	46.65m-p
	300	17.94e-h	22.67bcd	83.27d-h	174.10ef	73.32e-h	88.82efg	36.47ef	49.46cde
	400	14.98no	18.24k	22.13k	134.79t	12.20lmn	69.12t	28.25mn	39.05xyz

In the present investigation, the plant height, number of panicles per hill, panicle length, total grains panicle^{-1}, filled grains panicle^{-1}, seed set percentage and grain yield per plant were increased with increase in dose in all the treatments of gamma rays in rice genotypes studied in M_2 generation. Plant height, the most desirable values towards medium height were obtained from the genotype Giza 178 (109.67 and 110.33 cm) at 100 Gy and 400 Gy treatments, respectively. In addition to the most desirable values towards medium height were obtained from the genotype Giza 181 (103.33 and 107.67 cm) at 100 Gy and 200 Gy treatments in M_2 segregating generation, respectively. Plant height (cm) is widely used as an index in determining the biological effects of various physical mutagens.

The highest significant increase for number of panicles per plant (24.83 panicle), panicle length (23.80 cm) and grain yield per plant (51.16 g) were recorded for the genotype IR 58025B at dose of gamma irradiation 300 Gy treatment in M_2 segregating generation when compared to control. The most desirable filled grains panicle^{-1} was recorded by Giza 179 and Giza 181 (187.00 and 187.00) in control treatment. For seed set percentage was highest for GZ 9399 and IR 58025B (95.72 % and 95.15 %) at control treatment in M_2 generation, respectively.

2. Floral development of the mutant lines:

2.1. Analysis of variance:

The analysis of variance for floral traits tested in this study is presented in Table (5). Among all floral traits, pollen fertility (%) in M_2 segregating generation, anther width (mm), and number of pollen grains per anther in M_1 generation did not have significant differences for replications. Analysis of variance revealed highly genetic variation among all genotypes for all floral traits studied in M_1 and M_2 generations. The differences among treatments were also significant and highly significant for all studied floral traits. The genotype × dose interactions were significant and highly significant for all floral traits studied in M_1 and M_2 segregating generations except for anther width in M_1 generation, which indicated that the tested genotypes varied from treatments to the other.

Table 5. Observed mean sum of squares for floral traits of rice genotypes mutant in M_1 and M_2 generations.

Source of variance	df	Pollen fertility (%)		Anther length (mm)		Anther width (mm)		Basal pore length (µm)	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Replications	2	2.25**	1.65ns	0.0012**	0.0008**	0.0003ns	0.002**	33.59**	39.25**
Genotypes (G)	8	11.53**	23.17**	0.203**	0.044**	0.091**	0.105**	30113.39**	31681.07**
Doses (D)	4	3077.41**	2400.50**	0.043**	0.020**	0.025**	0.023**	1853.66**	1316.42**
G x D	32	1.09**	13.80**	0.0008**	0.008**	0.0002ns	0.0002**	45.93**	32.79**
Error	88	0.26	0.67	0.0004	0.0001	0.0002	0.0001	2.88	2.40
Total	134	-	-	-	-	-	-	-	-

Table 5: Continued.

Source of variance	df	Number of pollen grains per anther		Pistil length (Total stigma length) (mm)		Stigma non-brush-shaped part (mm)		Stigma width (mm)	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Replications	2	74.35ns	1202.76**	0.002**	0.014**	0.0006*	0.003**	0.0007*	0.003**
Genotypes (G)	8	417530.33**	428676.93**	1.137**	1.642**	0.080**	0.08**	0.015**	0.013**
Doses (D)	4	29634.92**	38729.77**	0.163**	0.272**	0.040**	0.043**	0.032**	0.043**
G x D	32	311.23**	517.16**	0.002**	0.070**	0.003**	0.001**	0.0003*	0.0003*
Error	88	140.97	49.93	0.0004	0.0006	0.0001	0.0001	0.0002	0.0002
Total	134	-	-	-	-	-	-	-	-

2.2. Effect of mutagens on the mean performance of floral traits in M_1 and M_2 generations:

Effect of gamma irradiation on restorers and maintainers rice was studied in M_1 and M_2 segregating generations under field condition. The mean performance in respect of various floral traits in M_1 and M_2 segregating populations are presented in Table (6).

Concerning the gamma irradiation doses Table (6) showed the high dose irradiation caused severe cell damage that led to pollen fertility decreased when compared to control in M_1 and M_2 generations Table (6) (Fig. 1), Likewise anther length, anther width, basal pore length, number of pollen grains per anther, total stigma length and stigma non-brush-shaped part decreased when compared to control in M_1 generation. While, the dose of 300 Gy gave the highest values for all floral traits studied viz. pollen fertility (93.59 %), anther length (2.35 mm), anther width (0.54 mm), basal pore length (246.85 µm), number of pollen grains per anther (1806.74), total stigma length (2.54 mm), stigma non-brush-shaped part (0.67 mm) and stigma width (0.45 mm) in M_2 generation (Fig. 2 and 3).

Table 6. Mean of performance for floral traits of rice genotypes mutations in M_1 and M_2 generations.

Treatment	Pollen fertility (%)		Anther length (mm)		Anther width (mm)		Basal pore length (µm)	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
								Doses (Gy)
Cont.	95.96a	94.83a	2.26a	2.28e	0.46a	0.46e	226.14a	229.41e
100	81.11b	85.60c	2.23b	2.31c	0.44b	0.49d	217.48b	235.89d
200	79.18c	84.41d	2.21c	2.33b	0.42c	0.51c	212.19c	241.15c
300	77.46d	93.59b	2.19d	2.35a	0.40d	0.54a	207.93d	246.85a
400	66.11e	71.35e	2.16e	2.31d	0.38e	0.52b	205.33e	244.33b
								Genotype
Giza 178	79.71cd	87.60a	2.18d	2.29e	0.36f	0.45f	175.17g	204.40f
Giza 179	81.33a	85.64e	2.25c	2.28e	0.38e	0.46e	255.28b	291.47b
Giza 181	79.61cd	86.64bc	2.28b	2.36b	0.42c	0.49d	298.36a	318.67a
Giza 182	78.29e	85.79de	2.31a	2.40a	0.40d	0.49c	250.71c	269.60c
GZ 9399	80.43b	86.32cd	2.25c	2.33d	0.38e	0.49d	175.87g	192.33g
IR 69625B	80.72b	87.07ab	2.27b	2.34cd	0.49b	0.60b	201.13e	231.93e
G 46B	79.41d	86.16cde	1.92e	2.23g	0.37f	0.43g	164.49h	181.00h
IR 58025B	80.38b	85.01f	2.18d	2.26f	0.38e	0.46e	203.68d	231.40e
IR 70368B	79.80c	83.36g	2.25c	2.35bc	0.60a	0.69a	199.63f	234.93d

Table 6: Continued.

Treatment	Number of pollen grains per anther		Pistil length (Total stigma length) (mm)		Stigma non-brush-shaped part (mm)		Stigma width (mm)	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
								Doses (Gy)
Cont.	1705.07a	1719.56d	2.20a	2.28d	0.54a	0.57e	0.33a	0.35e
100	1693.56b	1751.26c	2.16b	2.36c	0.52b	0.59d	0.31b	0.38d
200	1671.56c	1779.93b	2.11c	2.45b	0.50c	0.63c	0.29c	0.42c
300	1646.33d	1806.74a	2.05d	2.54a	0.48d	0.67a	0.27d	0.45a
400	1624.63e	1807.96a	2.00e	2.45b	0.45e	0.64b	0.24e	0.43b
								Genotype
Giza 178	1685.22f	1796.67e	1.68i	1.86i	0.48d	0.51f	0.26de	0.39d
Giza 179	1752.32c	1847.13b	2.06f	2.36f	0.52c	0.65c	0.28b	0.39d
Giza 181	1788.67b	1898.33a	2.09e	2.69c	0.58b	0.70b	0.27cd	0.35e
Giza 182	1797.93a	1899.73a	2.14d	2.48d	0.61a	0.74a	0.26e	0.40cd
GZ 9399	1702.50e	1820.87c	1.79h	2.01h	0.46f	0.62d	0.28bc	0.42b
IR 69625B	1712.00d	1793.87e	2.21c	2.43e	0.48d	0.60e	0.34a	0.44a
G 46B	1250.40h	1341.80g	1.98g	2.30g	0.35g	0.52f	0.28bc	0.40c
IR 58025B	1606.55g	1747.67f	2.50a	2.82a	0.47e	0.62d	0.29b	0.41c
IR 70368B	1718.47d	1811.73d	2.48b	2.80b	0.52c	0.60e	0.34a	0.45a

With respect to genotypes Table (6), the genotypes Giza 179 and Giza 178 gave the highest mean values for pollen fertility (81.33 and 87.60 %) in M_1 and M_2 generations, respectively (Fig. 1). In addition to, the Giza 182 gave the highest mean values for anther length (2.31 and 2.40 mm), number of pollen grains per anther (1797.93 and 1899.73) and Stigma non-brush-shaped part (0.61 and 0.74 mm) in M_1 and M_2 generations, respectively. Likewise, the genotypes IR 70368B gave the highest mean values for anther width (0.60 and 0.69 mm) and stigma width (0.34 and 0.45 mm) in M_1 and M_2 generations, respectively (Fig. 2 and 3). Also the genotypes Giza 181 (298.36 and 318.67 µm) gave the highest mean values for basal pore length in M_1 and M_2 segregating generations, respectively.

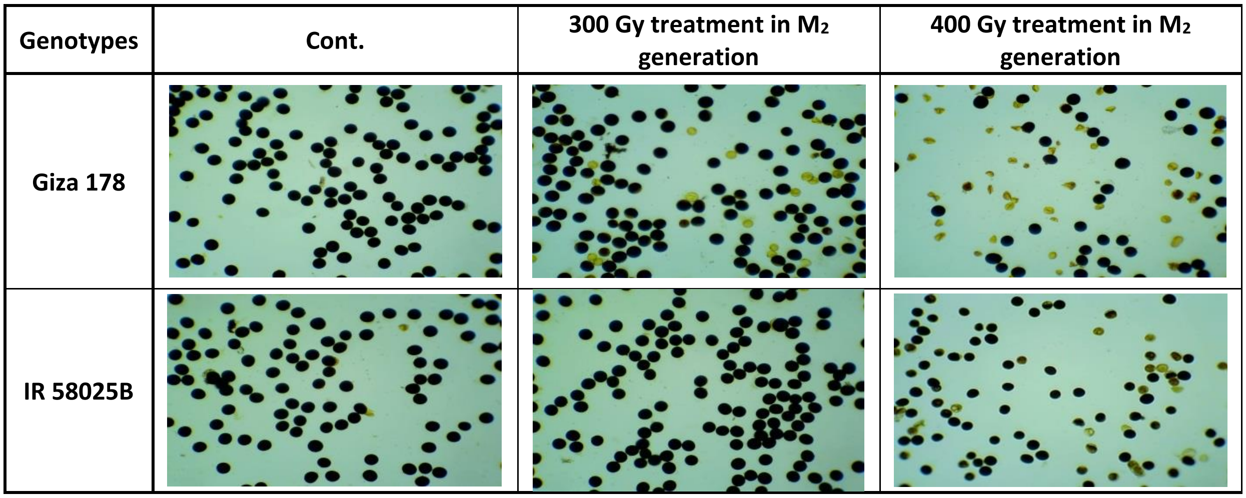

Fig. 1. Effect of gamma irradiation doses on pollen fertility in M_2 generations.

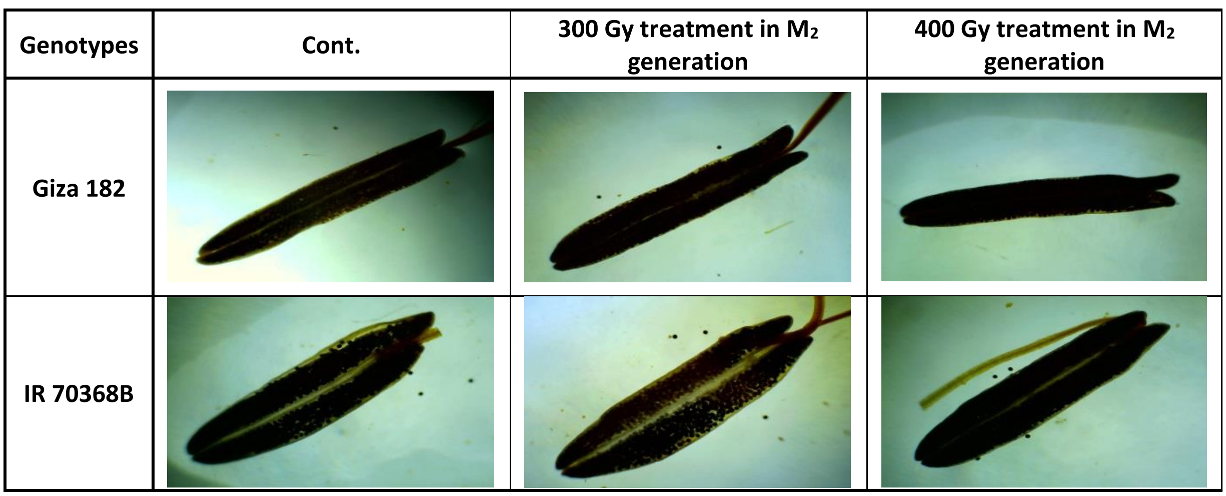

Fig. 2. Effect of gamma irradiation doses on dimensions of anther in M_2 generations.

Genotypes	Cont.	300 Gy treatment in M_2 generation	400 Gy treatment in M_2 generation
Giza 182			
IR 58025B			

Fig. 3. Effect of gamma irradiation doses on dimensions of stigma in M_2 generations.

2.3. Effects of interaction between genotypes and gamma rays:

The results in (Table 7) indicated that the interaction between the rice genotypes and gamma rays treatments on floral traits had a significant and highly significant effect on all this traits in M_1 and M_2 generations except for anther width in m_0 generation.

M_1 generation:

The effect of gamma rays on fertility of pollen of genotypes in M_1 generation was determined by computing the percentage of pollen fertility in anther sac of the floral Table (7). For pollen fertility, anther length, basal pore length, total stigma length and stigma width were decreased with increasing dose of gamma rays when compared to control. In contrast, for number of pollen grains per anther and stigma non-brush-shaped part showed no radio sensitivity at 0 Gy to 400 Gy of irradiation dose for all rice genotypes studied in M_1 generation.

Higher reduction in pollen fertility was noticed at 400 Gy of gamma rays in the all rice genotypes studied in M_1 generation. Maximum anther length, basal pore length and pistil length were observed at 100 Gy for Giza 182 (2.34 mm), Giza 181 (304.00 µm) and IR 58025B (2.57 mm), respectively. While minimum values were found with 400 Gy for G 46B (1.86 mm), G 46B (1.58 µm) and Giza 178 (1.64 mm), respectively.

Effect of interaction between genotypes and doses of gamma rays for Anther width was non-significant in M_1 generation. As compared to control high values for number of pollen grains per anther and stigma non-brush-shaped part were recorded at 100 Gy of irradiation dose for Giza 182 (1829.00) and (0.64 mm), respectively.

Maximum stigma width was observed at control treatment followed by100 Gy of gamma rays while minimum weight was observed at 100 Gy of gamma rays for all rice genotypes studied in M_1 generation.

Table 7. The interaction between rice genotypes and gamma irradiation doses effected on floral traits in M_1 and M_2 generations.

Genotypes	Doses (Gy)	Pollen fertility (%)		Anther length (mm)		Anther width (mm)		Basal pore length (µm)	
		M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Giza 178	Cont.	95.56cd	95.00a-d	2.28d-h	2.30n	0.40	0.41rs	185.50v	188.67v
	100	80.98hi	86.80e-h	2.21lm	2.32klm	0.37	0.44op	176.00x	196.33t
	200	79.20l	85.85e-h	2.21lm	2.34h-k	0.35	0.45mno	173.33xy	204.33s
	300	77.45opq	97.31a	2.13p	2.36e-h	0.35	0.47lm	171.67yz	217.67q
	400	65.36uv	73.04i	2.09q	2.11t	0.33	0.46lmn	169.33zA	215.00r
Giza 179	Cont.	97.08a	94.00a-d	2.29c-f	2.33jkl	0.42	0.43pq	266.39d	279.67h
	100	83.78f	85.90e-h	2.28ef-i	2.30n	0.41	0.44op	258.33e	289.00g
	200	81.08ghi	84.81e-h	2.25hij	2.28o	0.38	0.47lm	254.33f	296.00ef
	300	78.33mn	90.19cde	2.23jkl	2.26opq	0.36	0.49k	249.33gh	298.33e
	400	66.38st	73.29i	2.21lm	2.25pq	0.35	0.47lm	248.00hi	294.33f
Giza 181	Cont.	95.01de	93.67a-d	2.34ab	2.33jkl	0.45	0.45mno	304.48a	308.00d
	100	80.07jk	85.30e-h	2.30cde	2.34ijk	0.43	0.47l	304.00a	317.00c
	200	77.74nop	84.81e-h	2.28ef-i	2.36f-i	0.42	0.49k	297.00b	321.00b
	300	78.33mn	96.65a	2.26hij	2.38cde	0.41	0.52hi	293.33c	326.33a
	400	66.89s	72.79i	2.24jkl	2.37c-f	0.38	0.50jk	293.00c	321.00b
Giza 182	Cont.	94.58e	96abc	2.37a	2.37c-f	0.44	0.45mno	259.57e	262.33k
	100	79.20l	85.3e-h	2.34ab	2.39c	0.43	0.47lm	254.00f	264.67k
	200	77.07pq	84.81e-h	2.32bc	2.41b	0.40	0.5jk	251.00g	270.00j
	300	75.37r	90.33b-e	2.26f-j	2.43a	0.38	0.53gh	246.00i	276.000i
	400	65.22v	72.54i	2.25ij	2.39cd	0.35	0.51ij	243.00j	275.00i
GZ 9399	Cont.	96.72a	96.00abc	2.30cde	2.30n	0.42	0.44op	184.33v	185.00w
	100	81.5gh	87.10efg	2.28e-i	2.32klm	0.41	0.46lmn	180.00w	190.00v
	200	79.49kl	85.69e-h	2.25ijk	2.34h-k	0.38	0.49k	176.00x	192.67u
	300	78.04mno	90.01c-f	2.24jkl	2.36e-h	0.36	0.52hi	171.00yz	197.00t
	400	66.38st	72.79i	2.22klm	2.34h-k	0.34	0.52hi	168.00A	197.00t
IR 69625B	Cont.	96.51ab	96.33ab	2.31bcd	2.31lmn	0.53	0.55g	216.96m	217.33qr
	100	81.82g	85.30e-h	2.30cde	2.34ijk	0.51	0.58f	202.67op	228.00o
	200	80.07jk	85.40e-h	2.26g-j	2.35g-j	0.48	0.61e	198.00qr	232.67n
	300	78.33mn	95.53a-d	2.25ijk	2.37d-g	0.47	0.64d	195.00rs	238.33m
	400	66.89s	72.79i	2.24jkl	2.35g-j	0.45	0.63d	193.00st	243.33l
G 46B	Cont.	95.31cde	95.67a-d	1.97r	2.04u	0.39	0.40s	172.15yz	175.33y
	100	80.48ij	86.20e-h	1.94s	2.23rs	0.38	0.41rs	167.32A	179.00x
	200	78.67lm	85.49e-h	1.92s	2.26opq	0.37	0.44op	164.00B	184.00w
	300	76.73q	90.33b-e	1.92s	2.31lmn	0.35	0.46lmn	161.00C	189.00v
	400	65.87tuv	73.13i	1.86t	2.30n	0.34	0.45no	158.00D	177.67xy
IR 58025B	Cont.	96.99a	96.07abc	2.21lm	2.22s	0.42	0.42qr	220.41l	221.67p
	100	81.53gh	84.39e-h	2.21lm	2.24qr	0.40	0.45no	211.00n	227.00o
	200	80.07jk	81.85gh	2.19mn	2.27op	0.38	0.47l	200.33pq	232.67n
	300	77.16pq	96.70a	2.16no	2.30n	0.37	0.49k	195.00rs	238.00m
	400	66.13stu	66.01j	2.14op	2.27op	0.34	0.47l	191.67tu	237.67m
IR 70368B	Cont.	95.85bc	96.33ab	2.29c-g	2.30n	0.63	0.63d	225.47k	226.67o
	100	80.65ij	84.09fgh	2.28ef-i	2.33jkl	0.63	0.68c	204.00o	232.00n
	200	79.20l	80.97h	2.26hij	2.37d-g	0.61	0.70b	195.67rs	237.00m
	300	77.45opq	89.65def	2.24jkl	2.39cd	0.58	0.72a	189.00u	241.00l
	400	65.87tuv	65.76j	2.21lm	2.37d-g	0.55	0.70b	184.00v	238.00m

Table 7: Continued.

Genotypes	Doses (Gy)	Number of pollen grains per anther		Pistil length (Total stigma length) (mm)		Stigma non-brush-shaped part (mm)		Stigma width (mm)	
		M1	M2	M1	M2	M1	M2	M1	M2
Giza 178	Cont.	1738.12i-l	1736.67qr	1.71uv	1.73z	0.43st	0.45x	0.29jkl	0.32n
	100	1698.67mn	1785mno	1.70v	1.81yz	0.46qr	0.48w	0.28j-n	0.36lm
	200	1688.67nop	1795.00lm	1.68vw	1.88y	0.48pq	0.52v	0.26n-q	0.42efg
	300	1660.00qrs	1820.00ij	1.65wx	1.91xy	0.50m-p	0.56rst	0.25opq	0.45cd
	400	1640.67st	1846.67gh	1.64x	1.96vw	0.55ghi	0.56st	0.24pqr	0.41f-i
Giza 179	Cont.	1783.25cde	1795.00lm	2.13jk	2.15st	0.55gh	0.56rst	0.31fgh	0.33n
	100	1785.00cd	1830.00i	2.10kl	2.20r	0.55ghi	0.63lmn	0.31ghi	0.37klm
	200	1762.33e-h	1856.00fg	2.06mn	2.35no	0.52jkl	0.66hij	0.28j-m	0.40ghi
	300	1730.00jkl	1876.67de	2.02o	2.50j	0.51l-o	0.70ef	0.26n-q	0.43def
	400	1701.00mn	1878.00d	2.00op	2.59i	0.49op	0.68fgh	0.24qr	0.42efg
Giza 181	Cont.	1807.67b	1858.00fg	2.21gh	2.72ef	0.63b	0.65ijk	0.30hij	0.31n
	100	1827.00a	1885.33d	2.14ij	2.83d	0.61c	0.68fg	0.28jkl	0.33n
	200	1801.67bc	1908.33c	2.10kl	2.92b	0.59de	0.71de	0.27l-o	0.36lm
	300	1765.33d-g	1928.33a	2.03no	2.97a	0.56fg	0.75b	0.25o-r	0.39ijk
	400	1741.67h-k	1911.67c	2.00op	2.03u	0.52j-m	0.72cd	0.24pqr	0.37klm
Giza 182	Cont.	1835.98a	1846.67gh	2.24g	2.27q	0.67a	0.69ef	0.31fgh	0.32n
	100	1829.00a	1876.67de	2.20h	2.38mn	0.64b	0.72d	0.27l-o	0.37klm
	200	1803.33bc	1915.00bc	2.16ij	2.50j	0.61c	0.75b	0.26m-p	0.41e-h
	300	1772.00def	1935.33a	2.10kl	2.65gh	0.58ef	0.78a	0.23r	0.45cd
	400	1749.33g-j	1925.00ab	2.02o	2.59i	0.53ijk	0.74bc	0.21s	0.43ef
GZ 9399	Cont.	1760.84fgh	1775.33o	1.89r	1.90xy	0.52j-m	0.56st	0.34de	0.35m
	100	1717.67lm	1793.00lmn	1.84s	1.92wx	0.49nop	0.59pq	0.29ijk	0.4ghi
	200	1691.67no	1828.33i	1.78t	1.98v	0.46qr	0.63k-n	0.27k-o	0.43de
	300	1675.00o-r	1842.67h	1.74u	2.07u	0.43st	0.68fgh	0.25o-r	0.46bc
	400	1667.33pqr	1865.00ef	1.69v	2.18rs	0.40uv	0.65i-l	0.23r	0.43ef
IR 69625B	Cont.	1736.02i-l	1742.00q	2.30f	2.29pq	0.53hij	0.55tu	0.39a	0.39hij
	100	1724.33kl	1755.00p	2.27f	2.39mn	0.52j-m	0.57qrs	0.35cd	0.42efg
	200	1717.67lm	1787.00mno	2.23gh	2.43kl	0.50nop	0.61op	0.35cd	0.45cd
	300	1701.33mn	1827.00i	2.17i	2.50j	0.46q	0.66hij	0.32fgh	0.48ab
	400	1680.67n-q	1858.33fg	2.10kl	2.52j	0.41tuv	0.63lmn	0.28jkl	0.47ab
G 46B	Cont.	1277.02x	1297.00w	2.09lm	2.13t	0.42tu	0.45x	0.33efg	0.37klm
	100	1275.67x	1328.00v	2.02o	2.22r	0.38w	0.48w	0.31ghi	0.38jkl
	200	1250.67y	1355.00u	1.97p	2.31op	0.35x	0.53uv	0.27k-o	0.41f-i
	300	1235.67y	1369.67t	1.94q	2.45k	0.32y	0.58qr	0.25o-r	0.45cd
	400	1213.00z	1359.33tu	1.89r	2.41lm	0.30z	0.56rst	0.23r	0.41e-h
IR 58025B	Cont.	1654.43rs	1663.33s	2.63a	2.68fg	0.55ghi	0.56rst	0.33def	0.35m
	100	1633.67t	1726.67r	2.57b	2.76e	0.51k-n	0.59pq	0.31ghi	0.38jkl
	200	1611.67u	1763.00p	2.49c	2.85cd	0.48pq	0.63lmn	0.29ijk	0.42efg
	300	1581.00v	1803.67kl	2.43d	2.91b	0.44rs	0.67ghi	0.26m-p	0.45cd
	400	1552.00w	1781.67no	2.37e	2.89b	0.39vw	0.64j-m	0.24qr	0.42ef
IR 70368B	Cont.	1752.33f-i	1762.00p	2.60a	2.62hi	0.60cd	0.63lmn	0.38ab	0.40ghi
	100	1751.00fg-j	1781.67no	2.55b	2.75e	0.55ghi	0.56rst	0.37bc	0.42efg
	200	1716.33lm	1811.67jk	2.49c	2.83d	0.51k-n	0.59pq	0.35cd	0.46bc
	300	1696.67mno	1857.33fg	2.41d	2.91b	0.48pq	0.63mn	0.32efg	0.49a
	400	1676.00opq	1846.00gh	2.35e	2.88bc	0.44rs	0.62no	0.29ijk	0.48ab

M_2 generation:

This research investigated that the dose of irradiation 300 Gy showed the highest values of floral traits for all rice genotypes studied in M_2 segregating generation. In contrast, floral traits with 400 Gy dose resulted the lowest values for all rice genotypes in the M_2 segregating generation. Genotypes differed significantly from each other for floral traits at different radiation treatments.

On the other hand, pollen sterility was high in the genotypes Giza 178, Giza 181 and IR 58025B (97.31, 96.65 and 96.70 %) at 300 Gy of gamma rays in M_2 segregating generation, respectively. The highest values was obtained from Giza 181 for basal pore length, number of pollen grains per anther and total stigma length (326.33 µm, 1928.33 and 2.97 mm) at 300 Gy of gamma rays in the M_2 segregating generation, respectively (Fig. 1).

The highest values of anther length (2.43 mm), number of pollen grains per anther (1935.33) and stigma non-brush-shaped part (0.78 mm) were recorded with Giza 182 at 300 Gy of gamma rays in the M_2 segregating generation. This research found that the IR 70368B mutant was increased anther width (0.72 mm) and stigma width (0.49 mm) with a dose of gamma rays 300 Gy in M_2 generation (Fig. 2 and 3).

These results are in agreement with those of (Siddiq and Swaminathan 1968), which reported that gamma rays treatments induced high levels of sterility in rice plants. The pollen fertility in Samba Mahsuri (BPT 5204) after the gamma radiation treatment showed quite lower percentage in a dose 0.05 kGy (Kumar *et al.* 2013).

3. Genetic parameters:

Estimates of genetic variance, phenotypic variance, coefficient of genotypic variability (%), coefficient of phenotypic variability (%), heritability (%), genetic advance and genetic advance upon selection (%) for the studied characters in M_2 generation are given in Table (8).

The study of genetic variability is a basic requirement in any crop improvement programme for deciding the efficiency of selection, since greater the genetic diversity, wider is the scope for selection. Environmental effects influence the genetic variation. Hence, partitioning of overall variances as genetic (heritable) and non-genetic components becomes necessary for effective selection programme. In the present study, there existed significant differences among the genotypes for all the floral traits studied as revealed by ANOVA.

3.1. Growth and yield traits:

The data presented in Table (8) showed high genetic variance for days to 50% flowering (76.91) and plant height (29.70). However moderate values were obtained for filled grains panicle^{-1} (13.89) and low estimates of 2.81, 3.60, 0.37, 0.32 and 0.83, respectively, for germination percentage, number of panicles per hill, panicle length, seed set percentage and grain yield per plant.

High genetic coefficient of variation was found for days to 50% flowering and number of panicles per hill and the values ranged from 8.63 to 9.56.

In regard to the some growth and yield traits, germination percentage, plant height, panicle length, filled grains panicle^{-1} and seed set percentage showed lower genotypic coefficients of variability compared to the correspondent phenotypic coefficients of variability showing influence of the environment on these traits. The remaining traits; days to 50% flowering, number of panicles per plant, and grain yield per plant showed close values of the correspondent phenotypic coefficients of variability and in turn less effect of environment. These results are in agreement with the previous reports in rice that gamma rays induced considerable genetic variation for number of panicles per plant.

The heritable portion of the variation could be found out with the help of heritability estimates. Estimates heritability in broad sense (Hb) were increased by irradiation and the highest heritability values Table (8), had been obtained for days to 50% flowering (99.07%) followed by grain yield per plant (78.51%), plant height (76.77%) and number of panicles per plant (76.77%) while the lowest value of heritability was observed for seed set percentage (14.70%).

The expected genetic advance values for the growth and yield characters at M_1 generation are presented in Table (8). It ranged from (12.30%) for seed set percentage to (196.98%) for number of panicles per hill. It was low for germination percentage, filled grains panicle^{-1}, seed set percentage and grain yield per plant, indicating that the selection for the characters having high expected genetic advance would be effective for early generations.

Table 8. Estimates of genetic parameters for all studied traits over genotypes in M_2 generation.

Characters	GV	PV	GCV (%)	PCV (%)	Hb (%)	Gs	Gs (%)
Some growth and yield traits							
Germination percentage (%)	**2.81**	**4.11**	**1.81**	**2.19**	**68.28**	**34.53**	**37.20**
Days to 50% flowering (days)	**76.91**	**77.63**	**8.63**	**8.67**	**99.07**	**180.66**	**177.77**
Plant height (cm)	**29.70**	**38.69**	**4.64**	**5.29**	**76.77**	**112.26**	**95.56**
Number of panicles per hill	**2.79**	**3.64**	**9.43**	**10.75**	**76.85**	**34.44**	**194.20**
Panicle length (cm)	**0.30**	**0.69**	**2.61**	**3.97**	**43.13**	**11.20**	**53.68**
Filled grains panicle^{-1}	**11.45**	**17.22**	**2.05**	**2.51**	**66.46**	**69.69**	**42.14**
Seed set percentage (%)	**0.31**	**1.76**	**0.66**	**1.57**	**17.37**	**11.38**	**13.50**
Grain yield per plant (g)	**0.68**	**0.92**	**1.80**	**2.09**	**74.22**	**17.02**	**37.08**
Floral traits							
Pollen fertility (%)	**1.26**	**5.58**	**1.30**	**2.75**	**22.50**	**23.09**	**26.86**
Anther length (mm)	**0.003**	**0.005**	**2.28**	**3.10**	**54.05**	**1.09**	**46.98**
Anther width (mm)	**0.0070**	**0.0071**	**16.50**	**16.62**	**98.57**	**1.72**	**339.83**
Basal pore length (µm)	**2111.35**	**2122.13**	**19.18**	**19.23**	**99.49**	**946.56**	**395.18**
Number of pollen grains per anther	**28566.20**	**28750.17**	**9.53**	**9.56**	**99.36**	**3481.72**	**196.36**
Pistil length (Total stigma length) (mm)	**0.11**	**0.13**	**13.61**	**14.83**	**84.18**	**6.77**	**280.35**
Stigma non-brush-shaped part (mm)	**0.0053**	**0.0057**	**11.78**	**12.19**	**93.35**	**1.50**	**242.58**
Stigma width (mm)	**0.0010**	**0.0012**	**10.91**	**12.18**	**80.19**	**0.65**	**224.76**

GV = Genetic variance PV = Phenotypic variance
GCV = Genetic coefficient of variance PCV = Phenotypic coefficient of variance
Hb = Heritability in broad sense Gs = Genetic advance upon selection

3.2. Floral traits:

The data presented in Table (8), showed high genetic variance for basal pore length (2111.35) and number of pollen grains per anther (28566.20). However moderate values were obtained for pollen fertility (3.64) and low estimates of 0.003, 0.0070, 0.11, 0.0053 and 0.0010, respectively, for anther length, anther width, pistil length (Total stigma length), stigma non-brush-shaped part and stigma width.

High genetic coefficient of variation Table (8), for anther width, basal pore length and pistil length were obtained and the values ranged from 13.61 to 19.18.

In regard to the floral traits, pollen fertility, anther length, total stigma length, stigma non-brush-shaped part and stigma width showed lower genotypic coefficients of variability compared to the correspondent phenotypic coefficients of variability showing influence of the environment on these traits. The remaining traits; anther width, basal pore length and number of pollen grains per anther showed close values of the correspondent coefficients of variability and in turn less effect of environment. These results are in agreement with the previous reports in rice that gamma rays induced considerable genetic variation for number of panicles per plant.

The heritable portion of the variation could be found out with the help of heritability estimates. Estimates heritability in broad sense (Hb) were increased by irradiation and the highest heritability values Table (8) had been obtained for basal pore length (99.49%), anther width (98.57%), number of pollen grains per anther (99.36%) and stigma non-brush-shaped part (93.35%) followed by pistil length (84.18%) and stigma width (80.19%), while the lowest value of heritability was observed for anther length (54.05%) and pollen fertility (53.71%).

The expected genetic advance values for the floral characters in M_2 generation are presented in Table (8). It ranged from (41.36%) for pollen fertility to (395.18%) for Basal pore length. It was low for pollen fertility and anther length, indicating that the selection for the characters at delay generations, while the treats having high expected genetic advance would be effective for early generations. The estimates of genetic advance help in understanding the type of gene action involved in the expression of various polygenic characters. Thus the heritability estimates will be reliable if accompanied by high genetic advance.

DISCUSSION

With perusal of the results, it is evident that the genotypes and doses under study varied significantly for most of the traits, showing the presence of sufficient genetic variability in M_1 and M_2 generations. All of the traits that had significant genotype-dose interactions showed that the tested genotypes didn't do the same thing at all doses in the M_1 and M_2 generations. These results are in conformity with those of Kionget *et al.* (2008), who reported that gamma rays induced a reduction in germination and survival in African rice (*Oryza glaberrima*). Melki and Marouani (2009) observed that treating seeds with high rates of gamma radiation reduced germination and caused a corresponding decline in the growth of cereal plants. Harding *et al.* (2012) reported that germination percentage and effective tiller number decreased after gamma irradiation in rice. Shah *et al.* (2008) found that the frequency of physiological injury and mortality increased with the increase of mutagen doses. Shehzadet *et al.* (2011) found a reduction in plant height of up to 40 cm in the mutant Giza 171-M6 compared to the control while working with induced mutations using gamma rays.

In the present investigation, the higher the dosage of mutagens, the lower seed germination got delayed and reduced. The level of differentiation and development of the embryo at the time of treatment, as well as the amount of damage to growth processes like cell division, cell elongation, different stages of hormone production, and biosynthetic pathways, can all affect how likely a biological material is to cause mutations. Gamma irradiation leads to the ionization of molecules or atoms in materials and causes changes in DNA. Such genetic variability is critical to increasing the probability of gaining the desired features. If there are a lot of ionization bases or if they interact with the free radicals made by irradiation, this could lead to base deletion, which can stop germination.

The overall results indicated that germination percentage and pollen fertility (%) were more sensitive to gamma irradiation as compared to other growth, yield, and floral attributing characters in all rice genotypes. Therefore, changes observed in quantitative characters in the M_1 generation need to be studied in M_2 and later generations for understanding mutational changes in the genetic architecture of these important maintainer and restorer lines in rice.

Kumar *et al.* (2013) reported that pollen fertility decreased with the increase of gamma radiation dose in an approximately linear fashion. Miyahara (1997) reported that at 250 Gy of gamma rays dose, spikelet fertility was halved in rice. Pollen fertility may be influenced by many environmental factors as shown by the control. However, gamma radiation generally reduces the reproductive ability of the plant and increases the number of sterile pollen much more than the environmental effects. The results obtained were in accordance with the earlier reports of (Jain and Khandelwal, 2008) and (Ramya *et al.,* 2014) in blackgram; (Khan *et al.,* 2004) and (Singh and Singh, 2007) in greengram. The decrease in pollen fertility of rice after irradiation is considered to be due to chromosomal aberrations (Matsuo and Onozawa, 1961).

The breeders of hybrid rice require distinct restoring fertility lines. Restoration fertility could be determined by pollen fertility percentage, anther length, anther width, basal pore length, apical length, and number of pollen grains/anther significantly impact outcrossing rate (Tallebois *et al.,* 2017). Thenceforth, these characteristics should be considered in hybrid rice breeding programs. Under these circumstances, it is imperative to develop novel restorer lines distinguished by promising robust restoration ability to facilitate outcrossing and enhance hybrid rice production (Khumto *et al.,* 2018).

Based on the results shown, the plant's growth was stunted when it received the highest amount of radiation. This radiation injury could be due to the inhibition of DNA synthesis or other physiological damage that not only appeared in plant height but could also be manifested in the form of plant survival and the number of plant organs (Nwachukwu *et al.,* 2009). The irradiation of seeds with high doses of gamma rays disturbs the synthesis of proteins, hormone balance, leaf gas exchange, water exchange, and enzyme activity, which may be the possible causes of the adverse effects of gamma radiation on plant height in the present investigation.

Increasing the dose of gamma-rays decreased the mean number of filled grains per panicle, while the mean number of panicles per plant increased. The coefficient of variability increased by increasing the mutagenic dose for the studied characters, indicating the possibility of selecting promising mutants in future generations (Gomma *et al.,* 1995). High coefficients of variability were recorded for the number of filled grains per panicle and the number of panicles per plant in the M2-generation (Basak and Ganguli, 1996). The highest coefficient of variation was given by the sterility percentage (Mehetre *et al.,* 1996). Previous results showed that radiation could induce both phenotypic and genotypic changes in rice (Britto *et al.,* 2011).

A comparison of characters based on GCV is more appropriate as it represents the heritable portion of total variability, while PCV estimates include environmental effects (Allard, 1960). Genotypic coefficient of variation alone is not useful for selection, and Burton (1952b) suggested that GCV together with heritability estimates would give the best picture of the extent of genetic gain to be expected by selection. Hence, the success of genetic advancement depends on genetic variability, heritability, and selection intensity. The results are in accordance with the findings of (Seetharamaiah *et al.,* 2001; Ushakumari *et al.,* 2002), who reported higher heritability estimates for anther length, stigma excretion rate, and panicle excretion rate. High heritability for stigma characters was reported by (Neves *et al.,* 1989).

CONCLUSION

Generally, the results indicated that some genotypes performed better than others for all growth, yield, and floral traits studied in M_1 and M_2 generations. A dose of 300 Gy gave the highest values for all growth, yield, and floral traits studied in the M2 generation. The highest values for growth and yield traits were recorded when using Giza 178, Giza 182, and the IR 58025B mutant with 300 Gy of gamma rays in the M_2 segregating generation. And also, the highest values for floral traits were recorded when using Giza 182 and the IR 70368B mutant with 300 Gy of gamma rays in the M_2 segregating generation.

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تحسين السلالات المعيدة والمحافظة للخصوبة في الارز بأشعة جاما

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يعتمد إنتاج تقاوى الأرز الهجين بشكل أساسي على صفات الزهرة وصفات المحصول للآباء المعيدة للخصوبة (R) والسلالات المحافظة على الخصوبة (B). والتي يمكن تحسينها باستخدام التربية بالطفرات لتحسين معدل التهجين مع السلالات العقيمة ذكريا سيتوبلازميا. وتعتبر صفات الزهرة وصفات النمو لـ CMS وسلالاتها المحافظة على الخصوبة والسلالات معيدة للخصوبة من العوامل الأساسية في إنتاج تقاوي الأرز الهجين، لأنها توثر على معدل التلقيح الخلطي في إنتاج التقاوي الارز الهجين.تم تعريض بذور خمسة اباء معيدة للخصوبة واربعة سلالات محافظة على الخصوبة بخمس جرعات مختلفة من أشعة جاما (صفر، 100، 200 ، 300 و 400 Gy) لدراسة تأثير جرعات تشعيع جاما على صفات النمو والمحصول وصفات الزهرة لهذه التراكيب الوراثية، وكذلك للحث على اختلاف التباين الوراثي لاختيار النباتات ذات الصفات المرغوبة.

أوضحت النتائج أن جميع صفات النمو والمحصول وصفات الزهرة التي تمت دراستها في جيل M_1 انخفضت مع زيادة جرعات أشعة جاما عند مقارناتها مع الكنترول. وسجلت جرعة اشعة جاما 300 Gy أعلى القيم لبعض صفات النمو والمحصول وصفات الزهرة التي تمت دراستها في الجيل الانعزالي M_2 عند مقارناتها مع الكنترول. والتفاعل بين التراكيب الوراثية × جرعات أشعة جاما كانت معنوية وعالية المعنوية لجميع صفات النمو والمحصول وصفات الزهرة التي تمت دراستها في الجيلM_1 وM_2 ماعدا عرض المتوك في الجيل M_1، مما يدل علي أن التراكيب الوراثية اختلفت بين جرعات اشعة جاما وبعضها. وتم تسجيل أعلى متوسط القيم لصفات النمو والمحصول للأصناف جيزة 178 وجيزة 182 و IR 58025B عند استخدام جرعة اشعة جاما 300 Gy في الجيل الانعزالي M_2. وتم تسجيل أعلى متوسط القيم للصفات الزهرية للأصناف جيزة 182 و IR 70368B عند استخدام جرعة اشعة جاما 300 Gy في الجيل الانعزالي M_2.

قياسات مكونات التباين عموما كانت أعلى في النباتات المعاملة بأشعة جاما في جيلM_2. اظهرت النتائج ان نسبة متوسط القيم لدرجة التوريث العالية مع التقدم الوراثي المرتفع تم تسجيلها لمعظم الصفات التي تمت دراستها مما يشير إلى تحسين هذه الصفات عن طريق الانتخاب الظاهري البسيط. استخدام اشعة جاما ادي الي ظهور تنوعًا وراثيًا مختلفًا لتحسين سلالات المحافظة على الخصوبة والسلالات معيدة للخصوبة والحصول علي الصفات المرغوبة مثل طول النبات المرغوب والمبكرة وذات الإنتاجية العالية. أيضا، تحسين صفات الزهرة مثل طول وعرض المتوك، حيوية حبوب اللقاح، وعدد حبوب اللقاح في المتوك، وطول وعرض الميسم الكلي.

كلمات مفتاحية: السلالات المعيدة للخصوبة، السلالات المحافظة على الخصوبة، صفات الزهرة، اشعة جاما، المكونات الوراثية، الطفرات.