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Effect of different gamma irradiation doses on growth and yield attributes of selected tomato genotypes

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Abstract
That experiment was carried out to evaluate the effect of various doses of gamma irradiation on growth and yield attributing characters of selected tomato genotypes. Four levels of gamma irradiation *viz*. 200 Gy, 250 Gy, 300 Gy and Control (without irradiation) from ^{60}Co source were assigned to three genotypes *viz*. ELTS-100, ELTS-200, and ELTS-300. Results revealed that the gamma irradiation significantly affected on growth and yield attributing characters of three tomato genotypes using Randomized Complete Block Design (RCBD) with three replications. Collected data were subjected to analysis of variance and pertinent means were separated using least significant difference at a 5% level of probability. Gamma irradiations at 200 Gy on ELTS-200 genotype showed the greatest result as a single factor or in combinations. In combinations, ELTS-200 genotype treated with 200 Gy gamma irradiation showed the superior result on plant height (160.13 cm), leaf number per plant (161.60), leaf length (20.30 cm), leaf diameter (20.57 cm), fruit weight per plant (3.95 kg), fruit yield per plot (35.55 kg) and the yield per hectare (88.88 t/ha). In the other hand, ELTS-300 genotype under the control treatment showed the lowest result on all parameters such as, plant height (113.26 cm), number of leaves per plant (122.07), number of branches per plant (20.40), number of flower cluster per plant (22.00), Leaf length (17.26 cm), leaf diameter (17.26 cm), number of fruits per plant (41.87), fruit weight per plant (2.31 kg), fruit yield per plot (20.81 kg) and the yield per hectare (52.02 t/ha). The genotype, ELTS-200 that was treated with 200 Gy irradiation showed outstanding superiority for plant growth and yield attributes.

Keywords: Tomato; gamma irradiation; genotypes; growth; yield

Introduction
The tomato (*Solanum lycopersicum* L.) fruit is one of the most popular, as well as important, commodities in the world (Naika *et al.*, 2005) [27]. Tomatoes are one of the world's largest vegetable crops in terms of production volume (USDA, 2023) [33] and were among the top-ranking Vegetable Crops (FAO, 2023) [16]. It is a member of the Solanaceae family and the genus *Lycopersicon*. It is also a known vegetable of nightshade family. Bangladesh Bureau of Statistics (BBS, 2022) [7] also showed tomato production was 0.442 million tons in fiscal year 2021-2022 of which above 98 per cent were produced in winter. According to the Food and Agriculture Organization (FAO, 2021) [15], the total cultivated area in the world approximately 1.39 billion hectares (ha) and the global tomato production was approximately 183.5 million tons. The crop's global production has been consistently increasing since the beginning of the twenty-first century, with an average annual growth rate of 2.4%. It is often referred to as 'the poor man's orange' because of its high vitamin, malic acid, and citric acid contents, and the fact that it serves as a fine appetizer. As a processing crop, it takes first rank among the vegetables. Despite the fact that the tomato was not considered a valued food until around a century ago, its value is now widely acknowledged. Tomato is a diploid crop (has 24 somatic chromosomes) with small genome size and can be reproduced by both seed and vegetative propagations. In Bangladesh 95 mutant varieties of different crops have been developed by BINA, which were released by the National Seed Board (NSB) for cultivation in the farmers' fields (Azad *et al.*, 2012) [6]. A study by Cao *et al.*, (2017) [10] reported that the application of gamma radiation had a positive effect on the number of branches in tomato plants at low to moderate doses up to 100 Gy. The researchers observed an increase in the number of branches in tomato plants by up to 28% with increasing radiation dose,

after which the branching was reduced at higher doses.

Certain agricultural products are also sterilized using ionizing radiation to extend their shelf life or to lessen the spread of pathogens when they are traded within or between nations (Melki and Salami, 2008) [26]. Through induced mutations it is possible to improve a single trait without causing extensive disruption in the genome. Crop improvement through induced mutation has been shown to be a successful strategy for increasing yield, quality, and resilience to both biotic and abiotic challenges (Bibi *et al.*, 2009; Nichterlain *et al.*, 2000) [8, 29]. Thus, induced mutations can also play a vital role in improving complex quantitative traits including tolerance to abiotic stresses. Wilde (2015) [34] showed that many important traits for plant domestication and improvement have resulted from human selection for novel alleles of structural or regulatory genes. In addition to genetic mutations that occur naturally, chemical and physical mutagenesis have been used to create novel alleles in plants. Inducing genetic variation in plant-forming cells while reducing chimeras, sterility, and lethality is the aim of mutagenesis. Mutation breeding can be stream genotyped by screening for genotypes with candidate gene mutations that were induced either naturally or experimentally. Bioinformatics and sequence data from the growing number of sequenced plant genomes will simplify the identification of candidate genes for qualitative traits. Ahuja *et al.*, (2014) [2] Gamma radiation has been shown to cause metabolic and biochemical changes in plants1. In one study, gamma radiation was applied to four varieties of potato plants at doses of 10, 20, 30 and 40 Gray (Gy) and the effect on growth was measured. The study found that the average number of plant branches increased at a dose of 30 Gy. Another study found that gamma radiation can help cereal crops by increasing growth characters like plant height, number of tillers per plant and yield. Ismaeel *et al.*, (2018) [19] recorded that maximum number of branches plant per plant (34) in the variety of 017875 and the minimum number of branches plant per plant (14) in the Roma variety. Ahmed *et al.* (2013) investigated the influence of different gamma radiation doses (0, 25, 50, 75, 100, and 150 Gy) on the growth, yield, and quality of two tomato varieties. The result showed that the number of floral clusters per plant increased initially with low doses of gamma radiation (up to 50 Gy) and then decreased at higher doses. Al-Suhaibani *et al.*, (2017) [3] found that exposing tomato seedlings to gamma radiation at doses ranging from 50 to 200 Gy resulted in a significant increase in the number of flower clusters per plant. The authors suggest that this increase in flowering may be due to changes in plant hormone levels caused by the radiation. Elsayed *et al.*, (2018) [14] compared the flowering behavior of six different tomato varieties under greenhouse conditions. Ashraf *et al.*, (2018) [5] reported that the highest yield per hectare was obtained from the variety L021 treated with a dose of 30 Gy gamma radiation, with an average yield of 76.20 t/ha. The lowest yield per hectare was obtained from the control treatment, with an average yield of 54.45 t/ha. the above facts, the present research work was undertaken to select the suitable genotype of tomato that ensure the higher growth and yield along with finding out the most effective gamma irradiation dose in relation to growth and yield characteristics of tomato; and to assess the effect of interaction between suitable gamma irradiation dose and genotype on growth and yield of tomato.

Materials and Methods

Sources of Materials

Three tomato genotypes *viz*. ELTS-100, ELTS-200 and ELTS-300 were used as the experimental materials. The Horticulture Division of the Bangladesh Institute of Nuclear Agriculture (BINA), located in Mymensingh, Bangladesh, was responsible for collecting all of the genotypes from England. Gamma rays (60Co) were used to irradiate the seedlings at varying doses of 200 Gy, 250 Gy, and 300 Gy. The seeds were irradiated with gamma rays (^{60}Co) at different doses of 200 Gy, 250 Gy and 300 Gy. The non-irradiated (control) seeds of all genotypes were also supplied along with the irradiated seeds. Major characteristics of this genotypes are given below:

Major characteristics of ELTS-100 genotype are- 1) Small sized plant with busy structure; 2) Fruit number is higher than other two genotypes; 3) Early fruit bearing capacity; 4) Fruit shape is round.

Major characteristics of ELTS-200 genotype are- 1) Elongated stem; 2) High yield potential; 3) Less insect attack; 4) Fruit shape is flat.

Major characteristics of ELTS-300 genotype are- 1) Plant height is medium; 2) Less insect attack; 3) Early fruit bearing capacity; 4) fruit shape is plum or egg-shaped.

Experimental site and Soil

The present research work was carried out in the experimental farm of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during the period from 17 October, 2022 to 28 March, 2023. The soil of the experimental area was to the Sonatola soil series of grey flood plain soil under the Agro-ecological Zone (AEZ-9) and belonged to the Old Brahmaputra Flood Plains Alluvial Tract (UNDP, 1988). The selected plot was high land, fertile, well drained and having pH 7.10. The nutrient status, physical and chemical properties of soil of the experiment al plots are given in (Table 1).

Table 1: Physical and chemical properties of the top soil with nutrient status (0-15 cm depth)

Physical properties of the top soil (0-15 cm depth)		**Chemical characteristics of the top soil (0-15 cm depth) of the experimental site**	
Constituents	**Results**	**Constituents**	**Results**
% Sand (0.2-0.02 nun)	33.25	Soil pH	7.10
% Silt (0.02-0.002 mm)	61.30	Organic carbon (%)	1.28%
% Clay (< 0.002) mm	5.45	Organic matter (%)	2.16%
Textural class	Silt loam	Total Nitrogen (%)	0.11%
Bulk density	1.35	Available Phosphorus (ppm)	12.06
Porosity (%)	46.67	Exchangeable K (meq. /100g soil)	0.19
		Available S (ppm)	18.10
		Available Zn (ppm)	1.50
		Boron	0.21

Source: Soil Science Division, Bangladesh Institute of Nuclear Agriculture (BINA), BAU Campus, Mymensingh (2023)

Climate and weather

The experimental site was under sub-tropical climatic zone which is characterized by heavy rainfall, high temperature, high humidity, relatively long day during kharif season (April-August) and relatively short day during robi season (November to April). Rainfall is generally low during October to March. Information regarding monthly maximum, minimum and average temperature, relative humidity, rainfall and average sunshine hours as recorded by Weather Yard of Bangladesh Agricultural University, Mymensingh during the experimental period and it has been presented in (Table 2).

Table 2: Monthly air temperature, rainfall, relative humidity and sunshine of the experimental site during for the period from November 2022 to March 2023

Year	Month	**Air Temperature(^{0}C)			**Relative humidity (%)	*Rainfall (mm)	**Sun Shine (Hours)
		Max	Min	Mean			
2022	November	30.4	18.3	24.4	81.6	0	7.9
	December	26.4	14.7	20.6	84.8	0	6.1
2023	January	24.4	12.3	18.3	83.5	0	5
	February	27.9	16.3	22.1	78.6	11	6.8
	March	29.9	19.8	24.8	76.7	110.2	8.2

* = Monthly total, ** = Monthly average

Source: Weather Yard, department of irrigation and weather management, Bangladesh Agricultural University, Mymensingh-2202

Treatment of the experiment

Factor A: Gamma irradiation doses *viz.* 200 Gy, 250 Gy, 300 Gy and Control (without irradiation)
Factor B: Collected three genotypes *viz.* (i) ELTS-100 (ii) ELTS-200 and (iii) ELTS-300

Experimental design and layout of the experimental plot

The layout of the experiment was in a Randomized Complete Block Design (RCBD) with three replications. Thus, the total number of plots came to thirty-six (12 x 3). Plot size was 4 m^2 (2 m x 2 m) with three rows and three column and each row and column contain tree plants (3 x 3). Distance between the blocks and between the plots of experimental area was 50 cm.

Land preparation

The experimental field was prepared thoroughly by ploughing and cross ploughing with power tiller. The weeds and debris were removed during land preparation. The clods were broken manually and land was leveled by laddering. Proper laddering was done to bring the soil to proper tilth and leveling.

Sowing and transplanting

The sowing was conducted on 17 October, 2022 and 25 days old seedlings were transplanted in the main field on 10 November, 2022. Transplanting was done at afternoon and after transplanting watering was done for few days.

Fertilizer application

Application of manures and fertilizers were done by standard recommendations and the rate of manures and fertilizers used in the experimental plots has been shown in (Table 3).

Table 3: Doses of recommended organic and inorganic fertilizer application

Source	Quantity (kg/ha)	Source	Quantity (kg/ha)
Cow dung	10,000	Gypsum	50
Urea	250	Zinc Sulphate	5
Triple Super Phosphate (TSP)	250	Others (Mustard (TSP) oil cake)	400
Muriate of Potash (MOP)	150		

At the time of land preparation, whole amount of well decomposed cow dung, triple super phosphate (TSP), muriate of potash (MOP) and half of the urea was applied to the field. Rest half of the urea were applied in two installments in equal quantity. The first installment was 15 days after transplanting and the second installment was given a week before flowering.

Intercultural operations

Weeding and mulching were accomplished as and when necessary to keep the crop free from weeds, better soil aeration and to break the crust. When the plants were well established staking was given to each plant by bamboo sticks to keep them erect. After transplanting, the seedlings were properly watered for 4 consecutive days. Then flood irrigation was given to the plants after each top dressing of urea. During early stages of growth pruning was done by removing some of the lateral branches to allow the plants to get more sunlight and to reduce the self-shading and incidence of increased insect infestation. Pruning was done one month after the transplanting and after the pruning 8 to 10 branches were kept per plant. As the weather was favorable during the cropping period, there was no significant pest infestation in the field; therefore, no pesticide was sprayed. During fruit development and maturity stage, another weeding was done for clean cultivation.

Harvesting

Depending on variable maturity time, harvesting date varied from genotype to genotype and also gamma dose depended. The fruits of different genotypes were allowed to ripe and collected separately for data collection.

Data collection

Each entry had five randomly chosen and tagged plants. Observations for the following characters were recorded using these tagged plants. From 15 to 75 days, the plant's height, number of leaves per plant, number of branches per plant, and number of flower clusters were counted every 15 days interval. At the mature stage, the leaf length and leaf diameter were measured. Following the completion of the five harvesting cycles, the total number of fruits and their weight were calculated.

Statistical analysis

The statistical tool MSTAT-C was used to statistically examine the growth, yield, and yield component data. The mean for all treatments were calculated and analysis of variance for all the characters was performed by F test. Significance of differences between the pairs of treatment means were evaluated by the least significance difference (LSD) test at 5% and 1% levels of probability (Gomez and Gomez, 1984) [17].

Results and Discussion

Plant height (cm)

The effects of three genotypes and different doses of gamma irradiation also showed a significant influence on plant height at 15, 30, 45, 60 and 75 days after transplanting (DAT) (Figure 1). The tallest plant was found in 200 Gy gamma irradiated plants of ELTS-200 genotype that was observed 24.57 cm, 53.12 cm, 106.71 cm, 134.31 cm and 160.13 cm respectively at 15, 30, 45, 60 and 75 days after transplanting (DAT) and the shortest plant height reached 15.26 cm, 21.56 cm, 48.27 cm, 83.65 cm and 113.26 cm respectively on those days in ELTS-300 genotype with the control treatment (Figure 1). This study shows the most similarity with the study of Maged *et al.*, (2016) [24] where they investigated the effect of gamma radiation doses (0, 25, 50, 100, 150, and 200 Gy) on tomato plants of different varieties, including Domestic, Oxheart, and Bonus. The highest plant height at any dose varied among the different varieties, ranging from 157 cm for Domestic at the 25 Gy dose to 119 cm for Bonus at the 200 Gy dose. This study showed dissimilarity results with the study of Arumuganathan *et al.*, (2020) [4] and Abdel-Monem *et al.*, (2013) [1] might be due to variations in soil and weather of the study region or mutation effect that induced by treating various doses of gamma radiation.

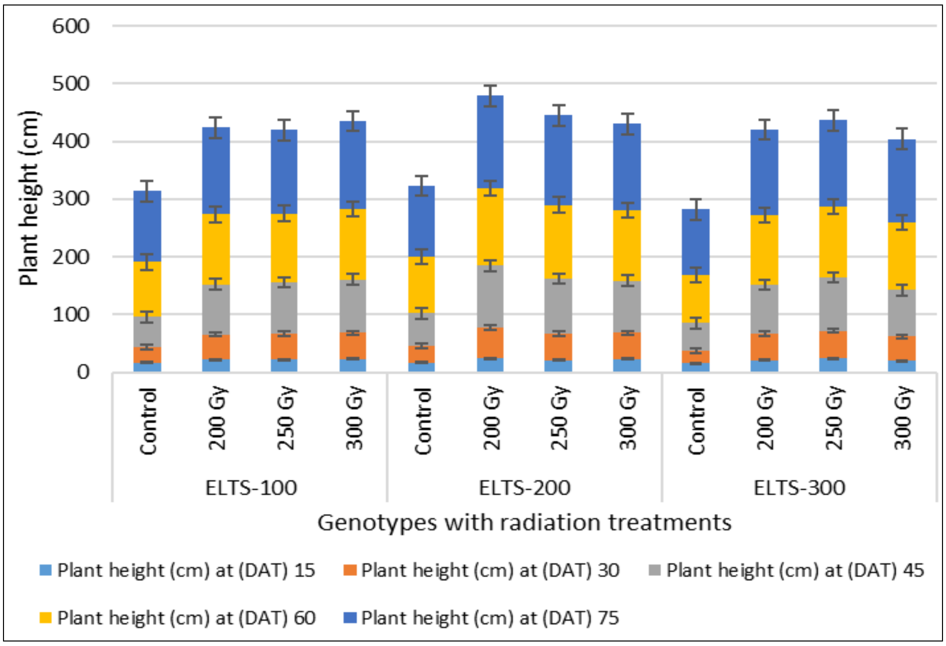

Fig 1: Effects of gamma irradiation and genotype on plant height at different days after planting of tomato. Vertical bars represent LSD (0.01)

Leaf number per plant

The significant difference showed in the effects of genotype and gamma irradiation on the leaves number per plant (Table 4) where the data was taken at 15, 30, 45, 60 and 75 days after transplanting (DAT). Among the combination effects, ELTS-200 genotype treated with the 200 Gy irradiation showed the highest number of leaves 13.00, 58.20, 107.27, 138.60 and 161.60 on those days whereas ELTS-300 genotype with the control treatment showed the lowest number of leaves 6.53, 35.93, 58.27, 94.87 and 122.07 in all day's interval (Table 4). This study also shows dissimilarity result with the study of Hasanuzzaman *et al.*, (2019) [18] showed a positive effect on variety and gamma radiation doses where the highest number of leaves per plant was observed at the 1 Gy dose for both tomato varieties. They showed that BARI tomato-8 had the highest number of leaves per plant 23.2 at the 1 Gy dose. On the other hand, the lowest number of leaves per plant was observed in the control group (0 Gy) where BARI tomato-15 had 12.8 leaves per plant. This variation might be due to the different level gamma irradiation dose and the effect of genotype. Moreover, the weather conditions and soil of the experimental area have caused. Biswas *et al.*, (2014) [9] showed that the maximum number of leaves was found from V3 (114.1/plant) while minimum from V2 (74.0/plant). Nemli *et al.*, (2009) [28] reported that variation findings in the genetic makeup of tomato varieties can lead to different growth habits. Additionally, exposure to different doses of gamma radiation can induce mutations in the DNA, which can also affect plant growth and branching.

Table 4: Effects of gamma irradiation and genotype on number of leaves per plant at different days after planting of tomato

Treatment(s)		No. of leaves per plant at different days after transplanting (DAT)				
		15	30	45	60	75
ELTS-100	Control	7.80	40.67	67.20	104.07	131.67
	200 Gy	11.20	51.13	94.27	128.67	153.67
	250 Gy	9.93	51.67	95.40	126.13	149.27
	300 Gy	11.27	54.53	99.40	128.87	156.27
ELTS-200	Control	7.33	42.47	74.67	108.27	134.13
	200 Gy	13.00	58.20	107.27	138.60	161.60
	250 Gy	10.47	54.67	99.67	130.93	155.53
	300 Gy	10.33	52.33	92.73	122.67	147.80
ELTS-300	Control	6.53	35.93	58.27	94.87	122.07
	200 Gy	10.27	52.07	93.67	127.00	148.93
	250 Gy	11.20	49.73	97.93	128.47	154.13
	300 Gy	9.40	50.60	88.60	121.67	146.80
$LSD_{0.05}$		1.58	8.11	9.15	10.10	10.80
$LSD_{0.01}$		2.15	11.02	12.44	13.72	14.68
Level of significance		**	**	**	**	**

** = Significant at 1% level of probability

Number of branches per plant

Among the treatments, a significant variance was found (Figure 2) where the greater number of branches was taken from the 300 Gy treated plants of ELTS-100 genotype that reached 2.47, 10.47, 14.53, 22.27 and 26.87 respectively at 15, 30, 45, 60 and 75 days after transplanting whereas the lowest number of branches was found from ELTS-300 genotype with the control treatment that reached 0.60, 5.60, 9.80, 16.93 and 20.40 respectively on those days' interval (Figure 2). This study is similarity result with the study of Malaker *et al.*, (2016) [25] the maximum (21.0) number of branches plant^{-1} was found in Japanese tomato Mini and the minimum number of branches (13.0) was recorded in BARI tomato 14. Ismaeel *et al.*, (2018) [18] recorded the maximum number of total branches plant^{-1} (34) in the variety of 0102.

According to the study conducted by Abdel-Monem *et al.*, (2013) [1], the highest number of branches per plant was (8.9) observed in the Control group (untreated) and the lowest number of branches per plant was (4.8) observed in the 1000 Gy gamma radiation dose. The study also showed the negative effect where the number of branches per plant decreased with increasing gamma radiation doses. The authors concluded that low doses of gamma radiation (up to 250 Gy) had a stimulatory effect on the growth and yield of tomato plants, while higher doses (500 and 1000 Gy) had negative effects. This dissimilarity might be due to the variation in gamma irradiation doses and the variation in genotype. Moreover, the weather conditions and soil of the experimental area have caused.

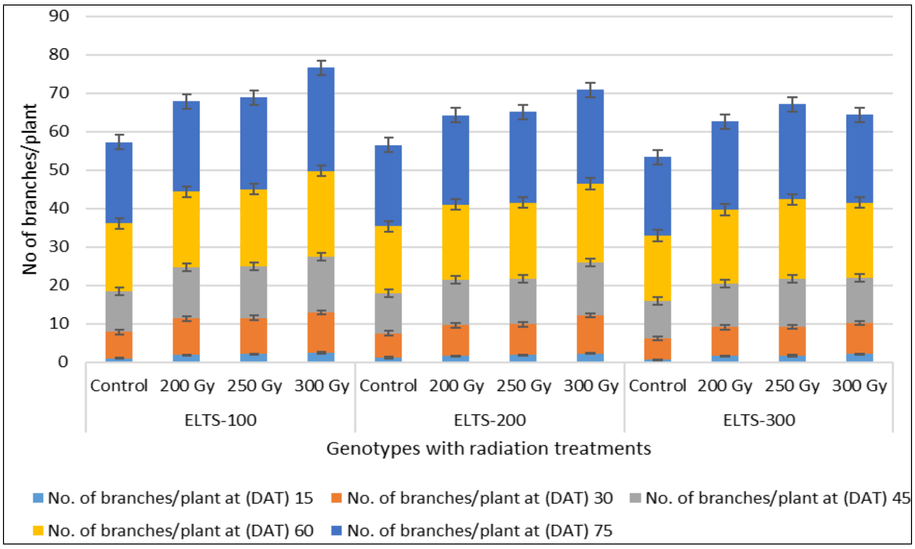

Fig 2: Effects of gamma irradiation and genotype on number of branches per plant at different days after planting of tomato. Vertical bars represent LSD (0.01)

Number of flower cluster per plant

The effects of three genotypes and different doses of gamma irradiation showed a significant influence on the number of flower clusters at 30, 45, 60 and 75 days after transplanting (DAT) (Table 5). ELTS-100 genotype with the 300 Gy treatment combination produced the maximum number of flower cluster per plant (33.67) at 75 DAT. In contrast, plants of the control treatment of all genotypes produced a smaller number of flower clusters, but ELTS-300 genotype with the control treatment produced the smallest number of flower clusters per plant (22.00) at 75 DAT. (Table 5). Solaiman *et al.*, (2006) [32] showed that the highest number of flower clusters per plant is 23.48 and the lowest is 13.55. Al-Suhaibani *et al.*, (2017) [3] found that exposing tomato seedlings to gamma radiation at doses ranging from 50 to 200 Gy resulted in a significant increase in the number of flower clusters per plant. El-Baker *et al.*, (2015) [11] investigated that a maximum number of flower clusters per plant (20) was found at 50 Gy and a minimum (6) at 100 Gy. This variation may be due to the changes in the gamma radiation doses and the soil and climatic conditions of the experiment area. In this experiment, leaf length showed significant difference among the various doses of gamma irradiation, three genotypes and in combinations.

Table 5: Effects of gamma irradiation and genotype on number of flower clusters per plant at different days after planting of tomato

Treatment(s)		No. of flower clusters per plant at different days after transplanting (DAT)				
		15	30	45	60	75
ELTS-100	Control	-	3.07	8.80	19.20	23.13
	200 Gy	-	4.53	11.47	24.20	27.93
	250 Gy	-	4.47	11.47	23.20	26.27
	300 Gy	-	5.87	13.07	30.80	33.67
ELTS-200	Control	-	3.13	10.13	17.67	23.33
	200 Gy	-	5.00	11.20	21.87	26.80
	250 Gy	-	4.13	10.87	24.07	28.13
	300 Gy	-	5.60	12.47	27.60	31.00
ELTS-300	Control	-	2.27	7.00	16.67	22.00
	200 Gy	-	4.40	10.93	23.93	27.07
	250 Gy	-	5.07	10.67	23.47	26.73
	300 Gy	-	4.20	9.53	21.87	26.20
$LSD_{0.05}$		-	0.78	1.20	3.20	3.07
$LSD_{0.01}$		-	1.06	1.63	4.35	4.17
Level of significance		-	**	**	**	**

** = Significant at 1% level of probability

Leaf length (cm): Combination treatments of the ELTS-200 genotype with the treatment of 200 Gy gamma irradiation produced the highest leaf length (20.30 cm) and the second highest result (19.39 cm) produced ELTS-100 genotype with the 300 Gy irradiant plant. On the other hand, plants of control treatment of all the three genotypes had shown the lowest leaf length where ELTS-200 genotype (18.21cm), ELTS-100 genotype (17.62 cm), and ELTS-300 genotype (17.26 cm) (Table 8). Rashid *et al.*, (2019) [30] examined that the negative effect with the increase of gamma radiation. Elhag and Albashier (2014) [12], reported that the highest range of leaf length (14.7 cm) was recorded in tomato plants exposed to 50 Gy of gamma radiation, while the lowest range (9.9 cm) was recorded in plants exposed to 500 Gy.

Leaf diameter (cm)

Leaf diameter was significantly affected by the effects of genotypes and gamma irradiation doses (Table 6). ELTS-200 genotype with the treatment of 200 Gy irradiation produced the highest leaf diameter (20.57 cm) and the second highest result (19.22cm) produced ELTS-100 genotype at 250 Gy irradiant plant. On the other hand, ELTS-300 genotype with the control treatment produced the lowest leaf diameter (15.80 cm) (Table 6). Johansen *et al.*, (2019) [21] showed a negative effect on overall tomato growth where the dose of 1000 Gy, "Rio Grande" had a leaf length of 11.84 cm, compared to 22.02 cm in the control group. Korkmaz *et al.*, (2019) [23] showed that the Priel variety at 1000Gy gives a maximum leaf diameter (9.22 cm) and where minimum leaf diameter (4.72 cm) in the Efes variety at 750 Gy. This dissimilarity might be due to the various doses of gamma irradiation and the mutation effect in the genotype.

Number of fruits per plant

Among the treatment combinations, a significantly maximum (83.67) number of fruits was taken from the 300 Gy treated plants of ELTS-100 genotype followed by the same irradiated plants of ELTS-300 genotype produced (69.93) and ELTS-200 produced (55.80). The minimum (41.87) number of fruits per plant produced from the control treatment plants of ELTS-300 genotype (Table 6). The findings are similar to the study to Kato *et al.*, (2017) [22] investigated that the highest fruit yield per plant was obtained at a dose of 300 Gy, which was about 1.8 times higher than the control.

Table 6: Effects of gamma irradiation and genotype on yield and yield contributing characters of tomato

Treatment(s)		Leaf length (cm)	Leaf diameter (cm)	No. of fruits/plant	Fruit weight/plant (kg)	Fruit weight/plot (kg)
ELTS-100	Control	17.62	17.02	62.60	2.37	21.33
	200 Gy	20.29	19.07	78.87	3.46	31.16
	250 Gy	18.86	19.22	81.67	3.36	30.28
	300 Gy	19.39	18.27	83.67	3.36	30.25
ELTS-200	Control	18.21	17.02	43.87	3.38	30.43
	200 Gy	20.30	20.57	55.87	3.95	35.55
	250 Gy	19.07	18.57	54.53	3.62	32.62
	300 Gy	20.06	18.28	55.80	3.57	32.09
ELTS-300	Control	17.26	15.80	41.87	2.31	20.81
	200 Gy	19.04	18.27	66.73	2.96	26.66
	250 Gy	18.40	19.00	65.80	2.60	23.44
	300 Gy	18.59	19.21	69.93	2.74	24.65
$LSD_{0.05}$		1.03	1.36	1.66	0.25	2.29
$LSD_{0.01}$		1.40	1.84	2.26	0.34	3.11
Level of significance		**	**	**	**	**

** = Significant at 1% level of probability

Fruit Weight per plant (kg)

In the treatment combinations, significantly the highest fruit weight per plant (3.95 kg) was taken from ELTS-200 genotype with the treatment of 200 Gy irradiation followed by the same irradiated plants of ELTS-100 genotype produced (3.46 kg) and ELTS-300 genotype (2.96 kg). The lowest (2.31 kg) fruit weight per plant was found from the control treatment plants of ELTS-300 genotype (Table 6). This study is similar to El-Sayed *et al.*, (2018) [13] showed the highest maximum fruit weight per plant was achieved in the mutant "Sameh", which produced a weight of 3.45 kg at a dose of 200 Gy, whereas Balady variety produced minimum fruit weight 2.73 kg per plant at a dose of 300 Gy.

Fruit yield per plot (kg)

Among the treatments, a significant difference was shown. The highest fruit weight per plot (35.55 kg) was taken from the 200 Gy treated plot of ELTS-200 genotypes followed by the second height weight (32.62 kg) taken from the 250 Gy treated plot of ELTS-200 genotype. The lowest fruit weight per plot (20.81 kg) found from the control treatment plot of ELTS-300 genotype (Table 6). Nemli *et al.*, (2009) [28] reported that variation findings in the genetic makeup of tomato varieties can lead to different growth habits. Additionally, exposure to different doses of gamma radiation can induce mutations in the DNA, which can also affect plant growth and yield.

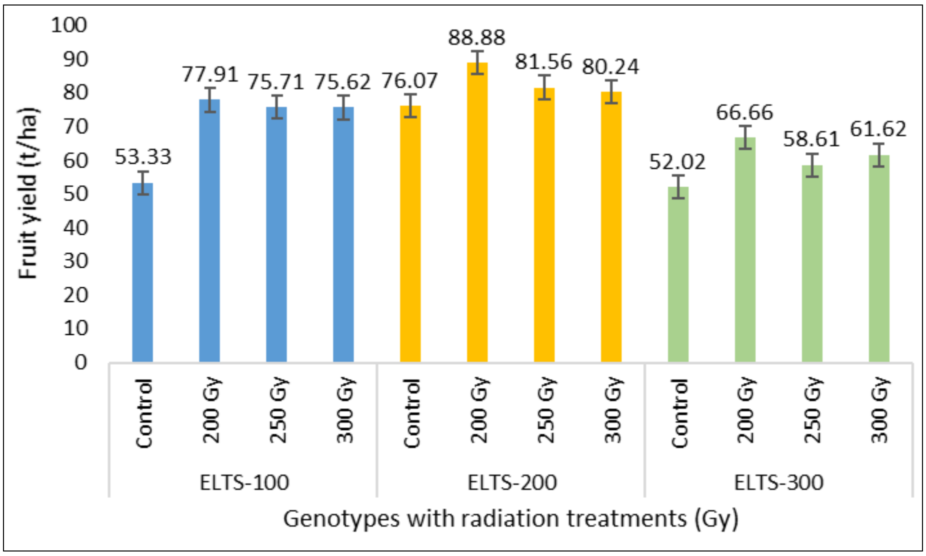

Fig 3: Effects of gamma irradiation and genotype on fruit yield (t/ha) of tomato. Vertical bars represent LSD (0.01)

Fruit yield per hectare (t/ha)

A notable difference was also seen amongst the combinations between genotypes and doses of gamma radiation. The ELTS-200 genotype treated with 200 Gy gamma irradiation produced the highest fruit output (88.88 t/ha), second-highest yield (81.56 t/ha) was found from ELTS-200 genotype with the 250 Gy irradiation. ELTS-300 genotype with the control treatment produced the lowest fruit production (52.02 t/ha) (Figure 3). This result is similar to Jafar *et al.*, (2018) [20] evaluated that a dose of 50 Gy resulted in the highest yield obtained from 'OT-11' at 78.74 t ha^{-1}. Sarmah *et al.*, (2013) [31] reported that a dose of 100 Gy gamma radiation on the highest yield was obtained from 'GCC-9' mutants at 76.78 t ha^{-1}. This variation may be due to the changes in the gamma radiation doses and the soil and climatic conditions of the experiment area. In this experiment, leaf length showed significant difference among the various doses of gamma irradiation, three genotypes and in combinations.

Conclusion

The present study was conducted to investigate the effect of different levels of gamma irradiation on the growth and yield of three exotic tomato genotypes. Considerers the treatment combinations, the highest yield (88.88 t/ha) was obtained from the ELTS-200 genotype with the treatment of 200 Gy and the lowest yield (52.02 t/ha) was obtained from the ELTS-300 genotype with the control treatment. For potential development of new varieties, further studies may be carried out to evaluate the mutant genotypes in the subsequent generations.

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