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Impact of Gamma Rays Induced Mutations on Morphological and Yield attributing Characters in Maize (*Zea Mays* L)

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Purpose: The objective of the present study was to assess the effect of different doses (100Gy, 200Gy, 300Gy, 400Gy, 500Gy) of gamma radiation on different morpho-agronomic characteristics of two cultivar of maize (*Zea mays* L). Morphometric characterization of the descriptive data included germination parameters, days to tassel and cob initiation and maturation, growth parameters, biomass and Yield parameters (yield parameters are yield per plant, yield per dose, cob length, grains number per cob and 1000 grains weight). The results of the present study revealed that lower doses (100Gy, 200Gy) of gamma radiation showed stimulatory effect on most of agronomic and morphological traits of maize. However, higher doses of 300Gy, 400Gy and 500Gy showed inhibitory effect for various traits of maize plant genotype.

Keywords: gamma radiation, morpho-agronomic characteristics, *Zea mays,* germination parameters, growth parameters, biomass parameters

INTRODUCTION

Maize (*Zea mays* L.) originated in central Mexico in around 5,000 BC. The crop was introduced to Europe in the sixteenth century, from where it spread to Africa and Asia. It is now one of the most widely-grown crops around the world in both temperate and tropical regions. It is among the 10 most important world crops by value. A gamma ray is a pocket of electromagnetic energy (photon) emitted by the nucleus of some radionuclides following radioactive decay. Gamma rays are the most energetic form of electromagnetic radiation, having 10 to 100 kilo electron volts energy level and greater Penetrating ability as compared to other radiation (Kovacs and Keresztes 2002). Gamma irradiation along with other high energy rays is a type of electromagnetic waves which have high penetration capacity into molecules and can bring about ionization of the subject material by removing their electrons (UNSC, 2000). Unlike X-rays which are also part of electromagnetic spectrum, gamma rays retain more energy and thus have a greater capacity for penetration into matter and ionization potentials (Burchfield, 2009). Such radiation generally originates naturally from galaxies and solar radiation as cosmic rays, from the decaying nuclei of radioactive materials which are external and internal earthly in nature and widely include isotopes of radium, potassium, uranium, cobalt, cesium, lead and carbon among many others (Underhill, 1995). Radioactive isotopes of certain atoms possess unsteady nuclei which can undergo decaying process over time resulting in the production of gamma rays (Fairand, 2001). Artificial sources of radiation are manmade gamma rays emitters such as Co-60 or Cs137 cells which are devised generally for industrial and medical purposes. Besides industrial and medical installation of gamma sources, testing of nuclear weapons and subsequent fallout of their radiation and nuclear power generations in reactors are also some of the important artificial sources contributing to the dissemination of gamma rays (Charles, 2001). Although generally considered as extremely hazardous for the health of the living organism, the use of gamma rays still has some beneficial application in agriculture, medicine and power generation. Mutation breeding of plants with gamma rays is one of the potentially useful applications in agriculture for desired outcomes. As a mutagenic agent, gamma radiation can induce both beneficial and harmful effects on pants (Kumar and Rai, 2009). Gamma irradiation application for modifying the genetic core of plants seems to be a promising technique as compared to plant breeding (Majeed et al. 2010). Effect of gamma irradiation on plant morphology, growth and developmental process is thought to be associated with induction of changes in cytology, biochemistry, genetics and physiology (El-Beltagi *et al.* 2011). Plants being living organisms, reserve genetic information in their chromosomes which control qualitative and quantitative characteristics such as those concerned with growth phenomena in field condition while resistance to decay in storage conditions. When struck by energizing radiation, the chromosomes in the propagating organs (usually seed) of plants undergo structural changes which modify the genetic structures (genes) in both positive and negative manner. Magnitude and duration of exposure to gamma irradiation are the key factors which either stimulate or suppress the genes concerned with the desired characters of plants. In general, higher doses have negative while low doses have stimulatory effects on plant growth. Changes in genome, biochemistry, physiological aspects and cytology incurred by radiation exposure are known to be correlated with intensity of radiation dose and duration of exposure, plant species and radiation environment. Different plant species show different responses to gamma irradiation. Similarly different doses of gamma irradiation exert different effects on plants. Generally, low doses do not impart harmful effects in contrast to higher doses which have drastic effects in most of the studied cases (Zaka et al. 2004; Dubey et al. 2007; EL Beltagi et al. 2011). The main objective of the study was to find out the impact of gamma radiation on morphological characterization and yield component of maize plant, and to find out which variety of maize show best response to gamma radiation.

MATERIALS AND METHODS

Collection of Seeds

Seeds of Zea mays namely; Jalal and Azam cultivars were procured from CCRI (Cereal Crop Research Institute) Peer Sabaq Nowshera. The collected seeds were packed in the plastic bags and brought to Nuclear Institute for Food and Agriculture (NIFA).

Treatment of Collected Seeds with Gamma Radiation

The collected seeds of Jalal and Azam two cultivars were subjected to gamma radiation using 60Co (Cobalt60) gamma source (Gamma Chamber900) in ambient condition at NIFA (Nuclear Institute for Food and Agriculture) Tarnab Peshawar. The doses of exposure were 100,200,300,400 and 500Gy.The experiments were designed in field under standard procedures.

Sowing of Seeds

The seeds were sown in the field in District Mohmand, Kado kor in May 2021.Treated seeds were sown in the field plots along with untreated control. The seeds were sown in a randomized complete block design in five replications with spacing of 75cm between the rows and 20cm between the plants (Gul *et al.* 2015). All the recommended cultural measures namely, irrigation, weeding, adding fertilizers, spraying pesticide and plant protection methods were carried out during the growth period of the crop.

Parameters

Various types of agro-morphological and yield attributing traits were measured during the plant’s life cycle. It includes the following:

Agro-Morphological Parameters

Days to germination first, germination percentage, days to first tassel initiation, days to first cob initiation, stem length / height in cm, leaves number, leaf length in cm, leaf width in cm, leaf area in cm^2,stem fresh weight in gram, stem dry weight in gram, stem moisture contents, leaf fresh weight in gram, leaf dry weight in gram, leaf moisture contents, root fresh weight in gram, root dry weight in gram, root moisture contents and days to first cob maturation.

Yield and Yield Components

Yield per plant, yield per dose, cob length in cm, grains number per cob and 1000 grains weight.

Days to germinate first

Number of days to germinate first in each treatment for both varieties of maize was counted from the date of sowing to the emergence of first seedling.

Germination percentage

After sowing, seeds were germinated and the data was recorded by using the following formula. (Chiapusio *et al.* 1997)

Germination percentage (%) = $\frac{\text{No. of germinated seeds}}{\text{Total No of seeds}} \times 100$

Days to first tassel initiation

Number of days to initiation of tassel was counted from the date of sowing to appearance of first tassels from each treatment.

Days to first cob initiation

Number of days to initiation of cob was counted from the date of sowing to initiation of first cob from each treatment

Stem length/height (cm)

The length of selected plants for both varieties of maize from each treatment was noted with the help of scale in cm.

Leaves number

The total number of leaves per plant of the selected plants was counted in each treatment.

Leaf length

Leaf length for selected plants of both maize variety in each treatment was measured by scale in centimetre.

Leaf width

Similarly leaf width for selected plants of both maize variety in each treatment was also measured by scale in centimetre

Leaf area

Leaf area was measured in centimetre for selected plants in each treatment by multiplying leaf length with leaf width.

Leaf Area = Leaf length × Leaf width

Fresh weight

The fresh weight of root, stem and leaf of selected plants of both maize variety was measured in gram by digital balance from each treatment.

Dry weight

After measuring the fresh weight of root, stem and leaf, they were placed in aseptic controlled condition in sun for thirty days to dry. After that, the dry weight of root, stem and leaf was measured in gram by digital balance for each treatment.

Moisture contents

Moisture contents of root, stem and leaf were determined according to the method used by Khan and Kulachi (2002). The moisture contents were determined by the following formula.

Moisture contents =Fresh weight – Dry weight

Cob length (cm)

Cob length was observed in cm through using the average length of control plants.

Grains number per cob

Number of grains in each cob was studied by comparing the number of grains per cob of all treated plants with their respective control plant`s cob.

1000 Grains weight

The 1000 grains weight was documented in grams from the targeted cobs in every one treatment.

Statistical analysis

The mean and ANOVA was calculated by using Microsoft Excel (MS Excel) with two way analysis followed by Dunnett`s post multiple comparison test to determine the variation in average of all tested parameters between irradiated and non-irradiated plants and significance was determined at $p<0.05$.

RESULTS

We studied the effect of various doses of gamma radiation on several attributes of two varieties of maize plant. We found that high doses of gamma radiation have inverse effect on the growth and yield characters of both varieties of maize plants. We observed that low doses of gamma radiations have significant effect on the attributes of both varieties of maize plants. The results were compared with control treatment and showed that gamma radiations at low doses have more influence than higher doses on both varieties of maize plants.

Germination percentage

We observed highest mean value of germination percentage about (96%) in control and 200Gy in Azam variety. Similarly, we also observed highest mean value of germination percentage about (92%) in Jalal variety at control treatment. However, the germination percentage was lowest at the higher doses of gamma radiation (Table 1.). We found a significant value ($P>0.05$) of germination percentage in both varieties at control, 100Gy, 200Gy, 300Gy and 500Gy doses of gamma radiation. However, we did not find the significant value ($P<0.05$) of germination percentage in both varieties at 400Gy dose of gamma radiation (Table 2.).

Days to germinate first

We found highest mean value of germination days about (8 days) in control and 300Gy dose of gamma radiation in Azam variety. Unlike Azam variety, we observed highest mean value of germination days about (9 days) followed by 8 days in Jalal variety at 500Gy and 300Gy doses of gamma radiation respectively. However, the value of germination days were lowest at the lower dose of gamma radiation (Table 1.). We observed a significant value ($P>0.05$) of germination days in both varieties at control, 100Gy and 500Gy doses of gamma radiation. However, we did not find the significant value ($P<0.05$) of germination days in both varieties at 200Gy, 300Gy and 400Gy doses of gamma radiation (Table

02.).

Days to first tassel initiation

We observed highest mean value for tassel initiation about (57 days) in Azam variety at 400Gy dose of gamma irradiation. Similarly, we also found highest mean value for tassel initiation about (62 days) in Jalal variety at 400Gy dose of radiation.

Table 1: Effect of different doses of gamma radiation on germination percent, days to germinate first and days to first tassel initiation of maize (*Zea mays* L)

Treatments	Germination percent		Days to Germinate first		Days to first tassel initiation	
	V1	V2	V1	V2	V1	V2
Control	96%	92%	8	7	42	48
100Gy	88%	84%	7	6	40	45
200Gy	96%	88%	7	7	45	48
300Gy	76%	84%	8	8	48	53
400Gy	68%	68%	7	7	57	62
500Gy	28%	16%	7	9	0	0

V1 (Azam Variety), V2= (Jalal Variety), Radiation doses (Control, 100Gy, 200Gy, 300Gy, 400Gy and 500Gy

Table 2: Mean square table for germination percent, days to germinate first and days to first tassel initiation

Parameters	Degree of freedom	Frequency (F)	F-critical	Probability (P-value)
Germination percent	**5**	**278.90**	**2.620**	**1.949E-20**
Days to germinate first	**5**	**2.2**	**2.620**	**0.087**
Days to first tassel initiation	**4**	**30.48**	**2.866**	**2.961E-08**

However, the number of days for tassel initiation was lowest at lower doses of gamma radiation (Table 01.). We found a significant value ($P>0.05$) for tassel initiation in both varieties at control, 100Gy, 200Gy, 300Gy and 400Gy doses of gamma radiation. However, we could not study the effect of gamma radiation on tassel initiation in both varieties at 500Gy dose, as the seedling did not survive more than 10 days after germination (Table 2).

Days to first cob initiation

Statistical analysis indicated that gamma rays have highly significant influence on days to first cob initiation of maize plant. We observed highest mean value for cob initiation about (64 days) at 400Gy dose of gamma radiation in Jalal variety. Similarly, we also observed highest mean value for cob initiation about (61 days) in Azam variety at 400Gy dose of gamma radiation (Table 03). However, the number of days for cob initiation was lowest at lower doses of gamma radiation. We found a significant value ($P>0.05$) for cob initiation in both varieties at 100Gy, 200Gy, 300Gy and 400Gy doses of gamma radiation. However, we did not observe the significant value ($P<0.05$) for cob initiation in both varieties at control sample (Table 4).

Plant height

Our result verified that gamma radiation has great significant impact on plant height. We found highest mean value of plant height about (183.89 cm) at 100Gy dose of gamma radiation in Azam variety. Similarly, we observed highest value of plant height about (150.36 cm) in Jalal variety at 100Gy dose of gamma radiation. However, the plant height was reduced in both varieties at higher doses of gamma radiation. (Table 3). We found a significant value ($P>0.05$)of plant height in both varieties at control,100Gy,200Gy and400Gy doses of gamma radiation. However, we did not find the significant value ($P<0.05$) of plant height in both varieties at 300Gy dose of radiation. We did not examine the effect of gamma radiation on plant height in both varieties at 500Gy dose, as the seedling derived from irradiated seeds did not remain alive more than10 days after germination (Table 4).

Number of leaves

Statistical analysis proved that gamma rays have imposed highly significant impact on leaves number of maize plant. We observed highest mean value of leaves number about (16.66 leaves) at 100Gy dose of gamma radiation in Jalal variety. While in case of Azam variety we found highest mean value of leaves number about (16.33 leaves) in control group. However, the leaves number was lowest at the higher doses of gamma radiation (Table 3).

We determined a significant value ($P>0.05$) of leaves number in both varieties at 100Gy, 200Gy, 300Gy and 400Gy doses of radiation. However, we did not determine the significant value ($P<0.05$) of leaves number in both varieties at control groups (Table 04).

Leaf length

Our result showed that gamma radiation has imposed significant impact on leaf length of maize plant. We observed maximum leaf length about (96.92 cm) at 100Gy dose in Jalal variety. Similarly, we also observed highest leaf length about (95.70 cm) in Azam variety at 100Gy dose of gamma radiation.

Table 3: Effect of different doses of gamma radiation on days to first cob initiation, plant height and leaves number of maize (*Zea mays* L).

Treatments	Days to first cob initiation		Plant height		Leaves number	
	V1	V2	V1	V2	V1	V2
Control	53	53	161.54±15.450	125.98±20.718	16.33±1.341	16.33±0.547
100Gy	53	55	183.89±12.679	150.36±34.443	16±1.341	16.66±1.483
200Gy	57	58	146.30±12.065	102.61±11.114	15.66±1.140	15±2.383
300Gy	59	62	68.07±16.777	69.09±23.212	13±1.516	12.33±1.816
400Gy	61	64	46.73±24.247	39.62±7.017	10.66±3.240	11.33±1.154
500Gy	0	0	0±0.000	0±0.000	0±0.000	0± 0.000

V1 (AzamVariety), V2= (Jalal Variety), Radiation doses (Control, 100Gy, 200Gy, 300Gy, 400Gy, 500Gy)

Table 4: Mean square table for days to first cob initiation, plant height and leaves number of maize plant.

Parameters	Degree of freedom	Frequency(F)	F-critical	Probability(P-value)
Days to first cob initiation	4	16.718	2.866	3.6381E-06
Plant height	4	59.200	2.866	8.391E-11
Leaves number	4	11.318	2.866	5.787E-05

However, the leaf length was decreased at the higher doses of gamma radiation (Table 05). We found a significant value ($P>0.05$) of leaf length in both varieties at 100Gy, 200Gy, 300Gy and 400Gy doses of gamma radiation. However, we did not find the significant value ($P<0.05$) of leaf length in both varieties of maize at non – irradiated groups (Table 06). We did not study the effect of gamma radiation on leaf length attribute in both varieties at 500Gy dose, as the seedling could not survive more than 10 days after germination (Table 06).

Leaf width

Statistical analysis indicated that gamma radiation has significant impact on leaf width of maize plant. We recorded highest mean value of leaf width about (9.29cm) in control and 100Gy dose of gamma radiation in Jalal variety. Similarly, we also observed highest mean value of leaf width about (9.24cm) in Azam variety at control treatment. However, the leaf width was reduced at the higher doses of radiation (Table 05). We observed a significant value ($P>0.05$) of leaf width in varieties at100Gy, 200Gy, 300Gy and 400Gy doses of radiation. However, we did not find the significant difference ($P<0.05$) for leaf width in both varieties at control treatments (Table – 4). In case of 500Gy dose, we could not study the impact of gamma radiation on leaf width character in both varieties due to premature death of seedlings (Table 06).

Leaf area

Our result showed that different doses of gamma irradiation have significantly influenced the leaf area of maize plant. We observed highest mean value of leaf area about (891.59 cm^2) at 100Gy dose of gamma radiation in Jalal variety. Similarly, we also observed highest value of leaf area about (844.598 cm^2) in Azam variety at 100Gy dose of gamma radiation. However, leaf area was significantly reduced at higher doses of gamma radiation (Table 05). We found a significant value ($P>0.05$) of leaf area in both varieties at control, 100Gy, 200Gy, 300Gy and 400Gy doses of gamma radiation (Table 05). However, we did not study the effect of gamma radiation on leaf area in both varieties at 500Gray dose of gamma radiation as the irradiated plants died in early stage of growth and development (Table 06).

Root fresh weight

Statistical analysis showed that impact of gamma radiation on root fresh weight of maize plant was not significant (Table 07). We found highest mean value of root fresh weight about (87.93g) at 200Gy dose of gamma radiation in Azam variety. Likewise, we also observed highest value of root fresh weight about (85.76g) in Jalal variety at 200Gy dose of radiation. However, the root fresh weight was reduced at the higher doses of gamma radiation (Table 07). We found a significant value (P>0.05) of root fresh weight in both varieties at 100Gy and 300Gy doses of gamma radiation. However, we did not find the significant value (P<0.05) of root fresh weight in both varieties at control, 200Gy and 400Gy doses of gamma radiation (Table 08). Data for root fresh weight .We could not collect data to study the effect of gamma radiation on root fresh weight at 500Gy doses in both varieties, as they did not survive more than 10 days after their sprouting.

Table 5: Effect of different doses of gamma radiation on leaf length, leaf width and leaf area of maize (*Zea mays* L)

Treatments	Leaf length		Leaf width		Leaf area	
	V1	V2	V1	V2	V1	V2
Control	89±14.841	89±16.045	9.244±1.375	9.29±1.213	833.656±230.636	824.30±178.269
100Gy	95.708±9.540	96.92±6.951	8.788±1.265	9.24±1.264	844.598±171.769	891.59±98.037
200Gy	82.354±17.163	84.12±15.181	8.178±1.113	8.94±1.156	683.354±220.224	745.58±125.552
300Gy	66.444±3.973	85.34±19.635	6.706±1.264	7.67±0.111	443.774±77.225	794.76±144.822
400Gy	63.396±14.034	64.61±16.041	6.248±2.211	5.33±1.733	420.192±202.279	357.07±149.366
500Gy	0±0.000	0±0.000	0±0.000	0±0.000	0±0.000	0±0.000

V1 (AzamVariety), V2= (Jalal Variety), Radiation doses (Control, 100Gy, 200Gy, 300Gy, 400Gy, 500

Table 6: Mean square table for leaf length, leaf width and leaf area of maize plant.

Parameters	Degree of freedom	Frequency(F)	F-critical	Probability(P-value)	F-critical
Leaf length	4	2.525	2.866	0.0730	2.866
Leaf width	4	7.901	2.866	0.0005	2.866
Leaf area	4	6.320	2.866	0.001	2.866

Table 7: Effect of different doses of gamma radiation on root fresh weight, leaf fresh weight and stem fresh weight of Maize (*Zea mays* L).

Treatments	Root fresh weight		Leaf fresh weight		Stem fresh weight	
	V1	V2	V1	V2	V1	V2
Control	66.26±10.751	69.43±30.531	15.56±3.097	14.10±2.360	245.43±68.674	279.86±107.144
100Gy	40.46±12.030	67.96±65.549	11.70±3.877	12.50±2.750	184.20±80.152	260.43±93.931
200Gy	87.93±23.884	85.76±24.228	17.23±3.881	17.73±2.758	324.50±97.868	360.70±87.377
300Gy	80.86±56.281	46.13±15.360	9.30±3.432	11.70±1.458	169.13±109.121	187.80±51.800
400Gy	48.70±14.815	49.43±16.510	11.33±1.475	9.20±0.476	98.60±30.543	163.03±13.884
500Gy	0±0.000	0±0.00	0±0.000	0±0.000	0±0.000	0±0.000

V1 (Azam Variety), V2= (Jalal Variety), Radiation doses (Control, 100Gy, 200Gy, 300Gy, 400Gy, 500Gy)

Leaf fresh weight

Our result showed that the impacts of gamma radiation on leaf fresh weight of maize plant were highly significant. We noted highest mean value of leaf fresh weight about (17.73g) in Jalal variety at 200Gy dose of gamma radiation. Similarly, we also observed highest value of leaf fresh weight about (17.23g) in Azam variety at 200Gy dose of radiation. However, the value of leaf fresh weight was significantly decreased at the higher doses of gamma radiation (Table 07). We found a significant differences (P>0.05) for leaf fresh weight in both varieties at 300Gy and 400Gy doses. However, we did not find the significant differences (P<0.05) for Leaf fresh weight in both varieties at control, 100Gy and 200Gy dose of gamma radiation (Table 08). We could not study the impact of gamma radiation on leaf fresh weight at 500Gy for both maize varieties, as the seedlings derived from seeds irradiated with 500Grays doses of gamma radiation, did not survive more than 10 days after their germination.

Stem fresh weight

Our result indicated that gamma radiation had significantly affected the stem fresh weight of maize plant. We observed highest mean value for stem fresh weight about (360.70g) at 200Gy dose of gamma radiation in Jalal variety. Similarly, we also found highest mean value for stem fresh weight about (324.50g) in Azam variety at 200Gy dose of gamma radiation. However, the stem fresh weight was lowest at the higher doses in both varieties (Table 07.). We found a significant value (P>0.05) of stem fresh weight in both varieties at control, 100Gy, 200Gy, 300Gy and 400Gy doses of gamma radiation (Table – 18). We could not collect data to study the effect of gamma radiation on stem fresh weight at 500Gy dose, because the seedlings did not remain alive more than 10 days after their sprouting (Table 08.).

Root dry weight

Statistical analysis showed that gamma rays had significant impact on root dry weight of maize plant. We observed highest mean value of root dry weight about (30.06g) at 200Gy dose in Jalal variety, showing stimulatory effect of gamma radiation on dry weight attribute of maize plant. Similarly, we also observed highest value of root dry weight about (20.03g) in Azam variety at 200Gy dose of gamma radiation. The root dry weight was significantly decreased at the higher dose of gamma radiation (Table 09.). We found a significant differences (P>0.05) in root dry weight for both varieties at 200Gy,300Gy and 400Gy doses of gamma radiation. However, we did not find a significant value (P<0.05) of root dry weight in both varieties at control and 100Gy dose of radiation (Table 09.). We could not gather data to study the effect of gamma radiation on root dry weight at 500Gy dose in both varieties, as they could not survive more than 10 days after their germination (Table 10.).

Leaf dry weight

Leaf dry weight showed significant interaction with different doses of gamma irradiation. We observed highest mean value of leaf dry weight about (4.30g) at 200Gy dose in Azam variety. Similarly, we also observed highest value of leaf dry weight about (4.16g) in Jalal variety at 200Gy dose of gamma radiation. However, the leaf dry weight was decreased at the higher doses of gamma radiation (Table 09.). We found a significant value (P>0.05) of leaf dry weight in both varieties at control, 100Gy, 300Gy and 400Gy doses of gamma rays. However, we did not find the significant value (P<0.05) of leaf dry weight in both varieties at 200Gy dose of gamma radiation (Table 10.). We could not examine the effect of gamma radiation on leaf dry weight in both varieties at 500Gy dose of radiation as they could not survive more than 10 days after their germination.

Stem dry weight

Our result showed that gamma rays had imposed a significant impact on stem dry weight of maize plant. We found highest mean value of stem dry weight about (61.70g) in Azam variety at 200Gray dose as compared to control and other lower and higher doses of gamma radiation. Likewise, we also observed highest value of stem dry weight about (54.56g) in Jalal variety at 200Gy dose of gamma radiation. However, the stem dry weight was significantly reduced at the higher doses of gamma radiation (Table 09.). We found a significant value (P>0.05) of stem dry weight in both varieties at 200Gy, 300Gy and 400Gy doses of gamma irradiation. However, we did not find the significant value (P<0.05) in both varieties at control and 100Gy dose of gamma

Table 8: Mean square table for root fresh weight, leaf fresh weight and stem fresh weight of maize plant

Parameters	Degree of freedom	Frequency(F)	F-critical	Probability(P-value)	F-critical
Root fresh weight	4	1.192	2.866	0.344	2.866
Leaf fresh weight	4	6.159	2.866	0.002	2.866
Stem fresh weight	4	4.484	2.866	0.009	2.866

Table 9: Effect of different doses of gamma radiation on root dry weight, leaf dry weight and stem dry weight of Maize (*Zea mays* L).

Treatments	Root dry weight		Leaf dry weight		Stem dry weight	
	V1	V2	V1	V2	V1	V2
Control	16.73±1.437	16.86±9.553	4.20±0.622	3.96±0.606	53.06±10.523	52.86±17.076
100Gy	14.70±7.778	14.70±31.377	3.16±0.971	3.73±1.059	40.93±20.112	42.63±20.104
200Gy	20.03±5.870	30.06±10.719	4.30±0.971	4.16±0.684	61.70±17.626	54.56±12.748
300Gy	16.46±10.300	11.00±4.624	2.33±0.758	2.80±0.676	25.86±14.864	32.50±13.497
400Gy	9.63±2.452	10.60±4.813	2.93±0.479	2.30±0.430	16.53±2.581	19.33±5.019
500Gy	0±0.000	0±0.000	0±0.000	0±0.000	0±0.000	0±0.000

V1 (AzamVariety), V2= (Jalal Variety), Radiation doses (Control, 100Gy, 200Gy, 300Gy, 400Gy, 500Gy)

Table 10: Mean square table for root dry weight, leaf dry weight and stem dry weight of maize plant.

Parameters	Degree of freedom	Frequency (F)	F-critical	Probability (P-value)

Root dry weight	4	2.851	2.866	0.050
Leaf dry weight	4	5.828	2.866	0.002
Stem dry weight	4	6.198	2.866	0.002

radiation (Table 10.). We could not examine the effect of gamma rays on stem dry weight in both varieties at 500Gy dose, because of the death of seedlings at early stage of growth and development.

Moisture content in root

Our result showed that gamma radiation had imposed non-significant impact on moisture content in root of maize plant. We observed highest mean value of moisture content in root about (67.90g) at 200Gy dose in Azam variety. Similarly, we also observed highest value of moisture content in root in Jalal variety at 200Gy dose of gamma radiation. However, root moisture content was decreased in Azam variety at 100Gy dose. While in Jalal variety we observed maximum reduction in root moisture content at 300Gy dose of gamma radiation (Table 11.). We found a significant value (P>0.05) of moisture content in root in both varieties at control,100Gy, 200Gy and 300Gy doses of gamma radiation. However, we did not find the significant value (P<0.05) of moisture content in root in both varieties at 400Gy dose of gamma radiation (Table 12.).

Moisture content in leaf

Statistical analysis revealed that the moisture content in leaf showed significant differences among varieties and treatments We observed highest mean value of moisture content in leaf about (13.56g) at 200Gy in Jalal variety. Similarly, we also observed highest value of moisture content about (12.93g) in Azam variety at 200Gy dose of gamma radiation. However, our result indicated that moisture content in leaf was lowest in variety Azam and variety Jalal at 300Gy and 400Gy doses respectively (Table 11.). We found a significant value (P>0.05) of moisture content in leaf in both varieties at 300Gy and 400Gy doses .However we did not find the significant value (P<0.05) of moisture content in both varieties at control, 100Gy, and 200Gy doses of gamma radiation (Table 12.).We could not study the effect of gamma radiation on leaf moisture content at both maize varieties at 500Gy, as the seedlings died in early stage of development.

Moisture content in stem

Our result concluded that the stem moisture content show highly significant differences among varieties and different doses of gamma radiation. We observed highest mean value of moisture content in stem about (306.13g) at 200Gy dose in Jalal variety. Similarly, we also observed the highest value of moisture content about (261.70g) in Azam variety at 200Gray dose of gamma radiation. However, the mean value of stem moisture content was reduced at the higher doses of gamma radiation (Table 11.). We found a significant value (P>0.05) of stem moisture content in both varieties at control, 100Gy, 200Gy, 300Gy and 400Gy doses of gamma radiation (Table 12.). Our result did not explain the effect of gamma radiation on stem moisture content in both varieties at 500Gy dose, as the seedlings derived from 500Gy irradiated seeds were died at early stage of growth and development.

Cob maturation

Our result indicated that gamma radiation has great impact on cob maturation. We observed maximum mean value of cob maturation about (106 days) at 300Gy and 400Gy doses of gamma radiation in Jalal variety. Similarly, we also observed highest value of cob maturation about (103days) in Azam variety at 400Gy dose of gamma radiation. The result indicated that the duration of cob maturation was delayed in both varieties at the higher doses of gamma radiation (Table 13.). We found a significant differences (P>0.05) for cob maturation in both varieties at control, 100Gy, 300Gy and 400Gy doses of radiation. However, we did not find the significant value (P<0.05) for the duration of cob maturation in both varieties at 200Gy dose of gamma radiation (Table 14.). We could not study the effect of gamma radiation on cob maturation attribute in both maize varieties at 500Gy dose, because the seedlings, derived from 500Gy irradiated seeds were died at early stage of growth and development

Table 11: Effect of different doses of gamma radiation on moisture contents in root, leaf and stem of Maize (*Zea mays* L)

Treatments	Moisture content in root		Moisture content in leaf		Moisture content in stem	
	V1	V2	V1	V2	V1	V2
Control	49.53±10.315	52.56±21.722	11.36±2.500	10.13±1.983	192.36±63.108	227.00±90.682
100Gy	25.76±7.131	53.26±36.991	8.53±2.918	8.76±1.971	143.26±61.840	217.80±75.326
200Gy	67.90±18.217	55.70±13.643	12.93±3.003	13.56±2.193	261.70±80.232	306.13±76.560
300Gy	64.40±46.562	35.13±11.612	6.96±2.710	8.90±0.998	143.26±94.883	155.30±42.872
400Gy	39.06±13.778	38.83±11.948	8.40±1.508	6.90±0.676	82.06±31.705	140.90±14.734

500Gy	0±0.000	0±0.000	0±0.000	0±0.000	0±0.000	0±0.000

V1 (AzamVariety), V2= (Jalal Variety), Radiation doses (Control, 100Gy, 200Gy, 300Gy, 400Gy, 500Gy).

Table 12: Mean square table for moisture content in root, moisture content in leaf and moisture content in stem.

Parameters	Degree of freedom	Frequency (F)	F-critical	Probability (P-value)	F-critical
Moisture content in root	4	0.816	2.866	0.529	2.866
Moisture content in leaf	4	5.981	2.866	0.002	2.866
Moisture content in stem	4	4.050	2.866	0.014	2.866

Cob length

Statistical analysis showed that there was no significant effect of gamma radiation on cob length. We observed highest cob length about (25.82 cm) in Azam variety at100Gy dose of gamma radiation. Similarly, we also observed highest cob length about (21.08 cm) in Jalal variety at 100Gy dose of radiation. However, the cob length was highly decreased at 300Gy in both varieties (Table 13.). We found a significant value (P>0.05) of cob length in both varieties at 100Gy, 200Gy and 400Gy doses. However, we did not find significant value (P<0.05) of cob length in control and 300Gy dose of gamma radiation (Table 14.). We did not study the effect of gamma radiation on cob length at 500Gy dose, for both maize varieties, owing of earlier death of plants. The result also indicated that variety Azam was more affected by gamma irradiation as compared to variety Jalal.

Grains number per cob

Our result showed that gamma radiation has imposed highest significant impact on grains number per cob of maize plant. We observed highest mean value of grains per cob about (517 grains) at control in Azam variety. While in Jalal variety we observed highest value of grains per cob about (420grains /cob) at 100Gy dose of radiation. The result also indicated that variety Jalal was more affected by gamma radiation in term of grains per cob as compared to variety Azam. However, the value of grains per was significantly decreased in both varieties at the higher doses of gamma radiation (Table 13.). We found a significant value (P>0.05) of grains per cob in both varieties at control, 100Gy, 200Gy, 300Gy and 400Gy doses of gamma radiation (Table 14.). In case of 500Gy dose, we could not analyze the effect of gamma radiation on grains number per cob in both varieties as the plant could not reach to maturity (Yielding stage).

Yield per plant

Our result indicated that gamma radiation has not imposed significant impact on yield per plant attribute of maize plant. We observed highest improvement in yield/plant about (2 cob/plant) at 200Gy dose of gamma radiation. We also observed highest value of yield/plant about (1.66 cob/plant) in Jalal variety at 100Gy and 300Gy doses of radiation. However, the value of yield per plant was lowest at control and higher doses of radiation (Table 15). We found a significant value (P>0.05) of yield per plant in both varieties at control, 100Gy, 200Gy and 400Gy doses of gamma radiation. However, we did not find the significant value (P<0.05) of yield per plant in both varieties at 300Gy dose of gamma radiation (Table 16). We could not study yield per plant in both maize varieties at 500Gy dose, as the seedlings in both varieties died within 10 days after their germination.

Yield per dose

Our result concluded that gamma radiation has not significant influence on yield per dose of maize plant. We observed highest value of yield /dose about (6 cob/dose) at200 Gray dose in Jalal variety. Similarly, we also observed maximum value of yield /dose about (5 cob/dose) in Azam variety at 100Gy and 300Gy doses of gamma radiation. (Table 15). We found a significant value (P>0.05) of yield per dose in both varieties at 200Gy dose. However, we did not find the significant value (P<0.05) of yield per dose in both varieties at control, 100Gy, 200Gy and 400Gy doses of gamma radiation (Table 16). We could not study the effect of gamma radiation on yield per dose in both maize varieties at 500Gy dose, as the seedlings in both varieties died within 10 days after their germination.

Table 13: Effect of different doses of gamma radiation on days to first cob maturation, cob length and grains number per cob of Maize (*Zea mays* L).

Treatments	Cob maturation		Cob length		Grains number/cob	
	V1	V2	V1	V2	V1	V2
Control	90	93	23.11±3.994	20.99±5.356	517±49.426	344±69.656
100Gy	85	93	25.82±2.113	21.08±2.171	514±340.476	420±60.630
200Gy	95	95	20.29±0.735	17.86±3.643	390.66±163.065	125.66±65.576

300Gy	99	106	16.25±4.153	17.35±3.968	82±58.923	0.00±0.000
400Gy	103	106	22.74±1.483	15.74±5.249	20.66±3.785	5.33±9.237
500Gy	0	0	0±0.000	0±0.000	0±0.000	0.00±0.000

V1 (Azam Variety), V2= (Jalal Variety), Radiation doses (Control, 100Gy, 200Gy, 300Gy, 400Gy, 5

Table 14: Mean Square table for cob maturation, rows number/cob and grains number/cob of maize plant.

Parameters	Degree of freedom	Frequency (F)	F-critical	Probability(P-value)	F-critical
Cob maturation	4	30.247	2.866	3.1614E-08	2.866
Cob length	4	3.182	2.866	0.035	2.866
Grains numb/cob	4	16.664	2.866	3.727E-06	2.866

Table 15: Effect of different doses of gamma radiation on yield/plant, yield/dose and 1000 grains weight of Maize (*Zea mays* L).

Treatments	Yield/plant		Yield/dose		1000 grains weight	
	V1	V2	V1	V2	V1	V2
Control	1.00±0.000	1.33±0.577	3	4	252	290
100Gy	1.66±1.154	1.33±0.577	5	4	260	264
200Gy	1.33±0.577	2.00±1.000	4	6	280	320
300Gy	1.66±0.577	1.66±0.577	5	5	218	0
400Gy	1.00±0.000	1.33±0.577	3	4	214	0
500Gy	0.00±0.000	0.00±0.000	0	0	0	0

V1 (Azam Variety), V2= (Jalal Variety), Radiation doses (Control, 100Gy, 200Gy, 300Gy, 400Gy, 500Gy)

Table 16: Mean square table yield per plant, yield per dose and 1000 grains weight of maize plant.

Parameters	Degree of freedom	Frequency (F)	F-critical	Probability (P-value)	F-critical
Yield/plant	4	0.884	2.866	0.490	2.866
Yield/dose	4	0.884	2.866	0.490	2.866
1000 grains weight	4	10816.77	2.866	4.874E-33	2.866

1000 grains weight

Statistical analysis showed that gamma radiation has imposed highly significant impact on 1000 grains weight of maize plant. We observed highest weight of 1000 grains about (320 g) in Jalal variety at 200Gy dose. Similarly, we also observed maximum weight of 1000 grains about (280 g) in Azam variety at 200Gy dose of gamma radiation. However, the weight of 1000 grains were decreased at the higher doses of gamma radiation. Higher doses (300Gy and 400Gy) of gamma radiation completely inhibited formation of grains in variety Jalal, so 1000 grains weight in variety Jalal at these doses was recorded as 0-gram weight due to unavailability of grains (Table 15). We found a significant value ($P>0.05$) of 1000 grains weight in both varieties at control, 100Gy, 200Gy, 300Gy, and 400Gy doses of radiation (Table 16). We could not analyze the effect of gamma radiation on 1000 grains weight character in both maize varieties at 500Gy dose, because the seedlings, derived from 500Gy irradiated seeds were died at early stage of growth and development.

DISCUSSION

Our result revealed that gamma radiation has significant effect on germination percentage of maize plant. We found a gradual decrease in germination percentage of test varieties (Azam and Jalal) with increase in dose of gamma radiation. Our findings were in-line with the finding of (Jan et al. 2011) who reported that irradiation with lower dosages of gamma rays significantly improved vegetative traits while higher dosages proved depressing for same parameters. The increase in germination may be due to the increased membrane permeability or changes in cellular oxidation potentials of membranes, which may correspond to breaking seed dormancy (Wang & Yu, 2000; Majeed *et al.* 2016). Our result also indicated that germination percentage was lowest at the higher doses of gamma radiation. In this case our result are in accordance with the findings of (Hameed et al. 2008) who found that germination percentage decreased significantly after higher irradiation dosages ranging from 350-500Gy. Maximum decrease in germination percentage was observed at 500Gy dosage. Gamma radiation might induce processes like auxin destruction, changes of the ascorbic acid content and physiological and biochemical disturbances which could induces the inhibition of plant germination and development (Shah et al.2008).

Statistical analysis of the data showed that radiation of gamma rays has great effect on days to germinate first. The control and 300Gy irradiated seeds of Azam variety recorded maximum germination days. However, germination days at other doses of gamma radiation were not highly significant among each other. Moreover, the germination days at various doses of gamma radiation in Jalal variety was significant. Seeds irradiated with higher dose (500Gy) showed maximum germination days. While lowest dose irradiated seeds showed rapid germination, indicating minimum germination days. However, germination days of 200Gy and 400Gy irradiated seeds were statistically similar to control seeds. It could be concluded that lower dose of gamma radiation caused stimulation in both varieties, leaded to rapid germination. The stimulating causes of lower doses of gamma rays on germination may be certified to the activation of RNA or protein synthesis, which occurred during the early stage of germination after seed irradiated (Abdel-Hady et al. 2008).

Statistical analysis showed that gamma radiation has significant impact on days to first tassel initiation. The number of days for tassel initiation showed gradual increase in both varieties of maize with the increase of doses of gamma radiation. However, the days for tasselling were lowest in both tested varieties of maize at the lowest dose of gamma radiation. Our findings were in-line with the findings of (Girija and Dhanavel., 2013) Who reported that days to first tasselling was delayed by gamma rays at higher dose of 40KR. Minimum days in first tasselling were observed in control (34.78) and maximum days in first tasselling were observed in 40KR of gamma rays (49.32 days). Moreover, we could not examine the impact of gamma radiation on days to tassel initiation in both Azam and Jalal variety of maize at highest dose (500Gy) of gamma radiation, because the seedling did no longer survive more than 10 days after germination.

Our result indicated that gamma radiation has great impact on cob initiation and cob maturation of maize plant. There was a significant variance between days to cob initiation and cob maturation in control and treated plants of both maize varieties. However, control plants of both varieties and 100Gy irradiated plants of Azam variety recorded statistically similar value for days to cob initiation. While days to cob maturation in Jalal variety was not significantly different in control and lowest dose irradiated plant and at 300Gy and 400Gy doses of gamma radiation. Days to cob initiation and maturation turned into delayed in each type on the higher doses of gamma radiation. Many researchers have identified mutants with alterations in late flowering and maturity index. (Gustafoon., 1947 and Kawal., 1963). Delay in cob initiation and maturation triggered by irradiations may be due to different dynamics which induce alteration (Smith and Kerestein, 1942). Moreover, we couldn't look at the effect of gamma radiation on cob initiation and cob maturation characteristics in each maize variety at 500Gy dose, due to the fact the seedlings, derived from 500Gy irradiated seeds were died at early stage of growth and development.

Our result verified that gamma radiation has great significant impact on plant height. Lower dose (100Gy) of gamma radiation markedly improved plant height in both variety of maize as compared to their control plants (Nassar et al. 2004). Asmahan and Nada. (2006) also found the increase in plant height with radiation in chamomile and tomato hybrid respectively. The increase in plant height might be due to poor translocation of both macro and micronutrients to reproductive parts due to damage of gamma irradiation; as a result, these are stored in the stem and thus promote plant height (Singh and Data, 2010; Majeed et al. 2017). However, the plant height declined in both varieties at higher doses of gamma radiation. Gamma irradiation-induced decline in plant height may be due to apical meristem damage (Patel and Saha, 1974), hindered synthesis of respiratory enzymes, and drop in the level of amylase activity (Reddy and Vidyavathi, 1985), and a temporary interruption in mitosis. Furthermore, we did not examine the effect of gamma radiation on plant height in both varieties at 500Gy dose, as the seedling derived from irradiated seeds did not remain alive more than10 days after germination. In this case our findings were in-line with the findings of (Marcu et al. 2013) who reported that plants derived from seeds exposed at higher doses (≤0.5 kGy) did not survive more than 10 days. Inhibition in plant height, induced through high-dose irradiation has been attributed to cell cycle arrest in the G_2/M phase during somatic cell division and/or to a variety of damages in the entire genome (Preuss et al. 2003).

Statistical analysis showed that gamma rays have imposed highly significant impact on leaves number of maize plant. Lower dose (100Gy) of gamma radiation showed stimulatory effect on leaves number. Production of the growth regulator, kinetin might have been stimulated, which may increase number of leaves (Asare et al. 2017). However, the average number of leaves produced decreased significantly with increased doses of gamma irradiation. In other words, we can say that the leaves number was lowest at the higher doses of gamma radiation, confirming the findings of (Yaqoob and Ahmad, 2003) in mung beans.

Our result showed that gamma radiation has imposed significant impact on leaf length of maize plant. Leaf length attribute, significantly improved at lower dose (100Gy) of gamma radiation in both tested variety (Azam and Jalal) of maize. However, it was decreased at the higher doses of gamma radiation. (Ilyas and Naz., 2014) also found similar results in *Cucurma longa*. According to them "gamma irradiation had significant effect on average length and width of leaves, inducing larger sized leaves at lower doses while higher doses had inhibitory effect on length of leaves". Moreover, we did not study the effect of gamma radiation on leaf length attribute in both varieties at 500Gy dose, as the seedling could not survive more than 10 days after germination. In this connection, it has been reported that increase in plant sensitivity after gamma irradiation may be probably due to reduced level of endogenous growth regulators, such as cytokinin, as a result of breakdown or lack of synthesis (Kiong *et al.* 2008).

Statistical analysis clarified that gamma radiation has significant impact on leaf width of maize plant. Control and 100Gy irradiated plants recorded maximum leaf width in both tested variety (Azam and Jalal) of maize. However, leaf width gradually decreased in both varieties with the increase of gamma radiation. Our result is in-line with finding of (Ilyas and Naz, 2014) who investigated that, size of leaf basically contributes to the vegetative biomass of plants. Gamma rays showed induced variation in the leaf size in *Cucurma decurrens,* with smallest (2-3mm) to largest (more than 1cm) leaf sizes, light green leaves, variable shapes and leaf margin. In *Cucurma longa* gamma irradiation had significant effect on average length and width of leaves, inducing larger sized leaves at lower doses while higher doses had inhibitory effect on length of leaves. In case of 500Gy dose, we could not study the impact of gamma radiation on leaf width character in both varieties due to premature death of seedlings.

Our result showed that different doses of gamma irradiation have significantly influenced the leaf area of maize plant. In the current study, lower dose (100Gy) treated plants of both varieties were found to have maximum leaf area as compared to their control plants. While higher dose irradiated plants of both maize varieties showed significant reduction in leaf area. Lebon., 2006 showed that low doses of gamma radiation have stimulating effects on the leaf surface while high doses have a depressive effect on the evolution of the photosynthetic surface. Indeed, according to (Lebon., 2006), irradiation of corn seeds causes stress in the plant. This water stress causes a significant reduction in the photosynthetic surface area. Lack of water causes a decrease in evapotranspiration through leaf senescence and a reduction in leaf area. However, we did not study the effect of gamma radiation on leaf area in both varieties at 500Gray dose of gamma radiation as the irradiated plants died in early stage of growth and development.

Statistical analysis showed that impact of gamma radiation on root fresh weight and dry weight of maize plant was not significant. Lower doses (200Gy) irradiated plants of both varieties showed significant improvement in case of fresh weight and dry weight of roots. Other doses of gamma radiation randomly affected the root fresh weight and dry weight in both variety of maize. Gamma irradiation enhances all the studied vegetative characters; this enhancement effect of gamma radiation was in harmony with (Hussein and Hamideldin., 2016) who reported significant increases of some traits as plant height, branches and leaf number, fresh and dry weights of root and root length using low doses of gamma irradiation. Lower dose (100Gy) caused significant decrease in root fresh weight and dry weight in Azam variety while Jalal variety showed maximum decrease in root fresh weight and dry weight at higher dose (400Gy) of gamma radiation. Furthermore, we could not collect data to study the effect of gamma radiation on root fresh weight and dry weight at 500Gy doses in both varieties, as they did not survive more than 10 days after their sprouting.

Similarly, we also found that gamma radiation imposed highly significant effect on leaf fresh weight and dry weight of maize plant. Lower dose (200Gy) of gamma radiation caused stimulatory effect in case of fresh and dry weight of leaf. While other selected doses of gamma radiation were found to have inhibitory effect on these attributes. At the same dose, Jalal variety showed more leaf fresh weight and dry weight than that of Azam variety. Present results can be compared with the studies of (Veeresh *et al.* 1995) who recorded an increase in shoot fresh weight of winged bean at lower doses, however, decrease at higher doses. Similarly (Kon et al*.* 2007) also reported a declining tendency in dry weight of shoot of long beans when exposed to higher gamma radiation doses. Reduction in fresh and dry weights of shoot might be due to reduced plant stature or reduced moisture contents in shoot due to radiation stress.

Our result indicated that gamma radiation had significantly affected the stem fresh weight and dry weight of the selected varieties (Azam and Jalal) of maize plant. Plants of both varieties, treated with lower dose (200Gy) of gamma radiation recorded maximum stem fresh weight and dry weight as compared to their corresponding control plants. However, Jalal variety showed more stem fresh weight and dry weight at the same doses than Azam variety. Higher doses caused a gradual decrease in stem fresh weight and dry in both selected variety of maize plants. Our results agreed with the consequences of (Veeresh *et al.* 1995) who reported that gamma radiation increased dry/fresh weights in lower intensities and then decreases them in higher intensities. Such decrease can be interpreted as decrease in leaf contents during the stress caused by radiation and the change in plant's metabolic system in addition to a relative increase in proteins synthesis rather than the membrane in fresh and dry weights respectively. We could not collect data to study the effect of gamma radiation on stem fresh weight at 500Gy dose, because the seedlings did not remain alive more than 10 days after their sprouting.

Statistical analysis revealed that moisture contents in leaf, root and stem showed significant differences among varieties and different doses of gamma radiation. Moisture contents in all the selected parts of both varieties of maize plants showed improvement at lower dose (200Gy) of gamma radiation. Except at 300Gy in Azam variety and 100Gy in Jalal variety, where moisture content in root increased compared to control rather than 200Gy, all other doses of gamma radiation decreased moisture contents in root, leaf and stem of maize plants. These results agreed with the consequence of (khalil et al. 1986), who clarified that reduction in various characteristics of plants due to radiation from gamma rays could be attributed to reduce in mitotic activity in meristematic tissues and reduced moisture content in fruit and seeds.

Our present work showed that gamma radiation has imposed highest significant impact on grains number per cob in both variety of maize plants. Maximum number of grains per cob were recorded in control plants of Azam variety followed by lower dose (100Gy) of gamma radiation. While in case of Jalal variety maximum improvement in grains number per cob was found at 100Gy (lower dose) dose of gamma radiation compared to control and other higher doses of radiation. Irfaq and Nawab., (2003) who explored the significant decrease in number of grain per cob and per plant with the raising of ionization radiation power. (Chapman et al. 1997) found additive kind of gene action for number of grains per cob with a few other yield associated parameters. Numerous genes were concerned to manage one characteristic. Further he also explained that mutagenic elements induce damaging variation due to number of grains in cob had been minimized to an excellent level in most dosage as evaluate into the control treatment.

Statistical analysis revealed that there was no significant effect of gamma radiation on cob length. Lower dose (100Gy) of gamma radiation had stimulatory effect on cob length in both maize varieties. While higher doses than 100Gy showed inhibitory effect on the same trait in maize plants. Furthermore, the cob length was highly decreased at higher dose (300Gy) in both varieties. (Tusuz and Balabanli., 1997) stated that the cob sizes significantly reduced at higher dosages and the seeds production was absolute and significantly associated with cob length. However, we did not study the effect of gamma radiation on cob length at 500Gy dose, for both maize varieties, owing of earlier death of plants. The result also indicated that variety Azam was more affected by gamma irradiation as compared to variety Jalal.

Our result indicated that gamma radiation has not imposed significant impact on yield per plant and yield per dose attribute in tested variety of maize plant. Lower dose (200Gy) treated plants of Jalal variety showed maximum improvement in yield/plant (cob number/pant) and yield/dose (cob number/dose) traits. However, such traits were observed to have increased in Azam variety at 100Gy and 300Gy doses as compared to control and other doses of gamma radiation. Moreover, other doses imposed inhibitory effect on yield/plant and yield/dose in both varieties as compared to lower doses. Banu *et al.* (2005) observed reduced yield in combined treatments with gamma rays and EMS in *Solanum melongena* L. Pavadai and Dhanvel., (2004) also observed remarkable loss of yield in soybean treated with chemical mutagens. . Reduction in cob number may be due to a probable inhibiting action of enzymes, changes in the enzymes activity and the toxicity of the mutagen *(*Larik., 1975). However, we could not study the effect of gamma radiation on yield per plant and yield per dose in both maize varieties at 500Gy dose, as the seedlings in both varieties died within 10 days after their germination

Statistical analysis showed that gamma radiation has imposed highly significant impact on 1000 grains weight of maize plant. Lower doses of gamma radiation (100Gy and 200Gy) caused improvement in 1000 grains weight of both maize varieties. However, higher doses of gamma radiation showed a gradual decrease in 1000 grains weight. Furthermore, higher doses (300Gy and 400Gy) of gamma radiation completely inhibited formation of grains in variety Jalal, so 1000 grains weight in variety Jalal at these doses was recorded as 0 gram weight due to unavailability of grains. Irfaq and Nwab, (2001) explored the inversely proportional effect of various levels of ionization radiation on different variety. There was an amazing reduction in 1000- seed weight as the ionization irradiation concentration raise the 1000 grain weight constantly reduce. Balderrama et al*.* (1997) detected accumulative gene action was most prominent within the dominance gene action towards 100-seed weight. Moreover, we could not analyze the effect of gamma radiation on 1000 grains weight character in both maize varieties at 500Gy dose, because the seedlings, derived from 500Gy irradiated seeds were died at early stage of growth and development.

CONCLUSIONS

The results of the experiment indicated that, irradiation of Maize (*Zea mays* L.) seeds from gamma rays caused some morphological and physiological variations, lower doses of gamma radiation enhance yield per plant, yield per dose, 1000 seeds weight, cob length, etc as well as some agro-morphological characterization including; days to first tassel initiation and maturation, cob initiation and maturation, days to first germination, germination percentage, plant height, leaves number, leaf length ,leaf area and fresh and dry weights of stem, leaf, root etc. Based on agronomic and morphological attributes, it has been concluded that, higher doses of 400Gy and 500Gy radiation reduced all the studied parameters of Maize varieties. The present study showed that, low doses radiation treatment from gamma rays is a better tool for improving agronomic and morphological attributes of maize.

Supplementary materials

The supplementary material / supporting for this article can be found online and downloaded at: https://www.isisn.org/article/

Author contributions

Conceptualization, M.A. and A.M.K.H; methodology, N.I., software, A.M.K.H.; validation N.I. and AMHK.; formal analysis, M.B, M.U, A..R, F.S, S.O.I,S.A.I and S.I .; investigation, N.I.; data curation, G.R writing-original draft preparation, A.M.H.K.; writing-review and editing, M.A. and A.M.H.K.; supervision, M.A. authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement

Not applicable.

Data Availability Statement

All of the data is included in the article/Supplementary Material.

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Conflict of interest

The authors declared that present study was performed in absence of any conflict of interest.

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