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Research Paper

Effect of gamma irradiation on germination and agronomic parameters of maize *(Zea mays* L.) genotypes

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Abstract

These experiments were conducted to determine the effect of the gamma irradiation seeds of four maize (*Zea mays* L.) genotypes (Var-113, Hudiba-1, Hudiba-2 and mug45). Four doses of gamma irradiation ranged from 50-200 GY (50, 100, 150 and 200GY). A laboratory and two field experiments were conducted. The laboratory experiment studied the germination percentage, shoot, root and shoot to root ratios of the germinated seedling, the obtained results revealed that the growth of the four genotypes was decreased with increasing of gamma irradiation doses. The field experiments were conducted to investigate the genetic variability among genotypes mean growth performances, such as days to flowering (tasseling & silking), plant and ear height and grain yield in two locations Shambat, College of Agricultural Research studies and Medani experimental farm of Agricultural Research Corporation. During the summer season of 2014, then there were a ranged in randomized complete block design with three replicates. The obtained results in field were shown that there were a significant difference among genotypes and doses (zero and 50GY), for genotypes and their interaction for most of the studied characters. This significance could be added of a great value for best selection in maize breeding for desirable traits. From this study, it could be conducted that, the gamma rays have negative effect on the germinations of the seedlings of maize genotypes. The increasing of the gamma irradiation decreased the growth of the germination. The genotypes treated with the high doses (150-200GY) were germinated but they failed to survive after 10 days from their germination. In addition the dose 100GY failed in the two locations, therefore, the suitable dose was 50 GY in both lab and field condition. The results of this study revealed that the availability of using gamma irradiation in any maize breeding program in the future.

Keywords: Genetic variability, genotypes, gamma irradiation, maize.

Introduction

Maize(*Zea mays*)is an important cereal crops throughout world[1,2]. Its ranks third among the cereal crops worldwide after wheat and rice, and grown over a wider geographical and environmental range than any other cereals[3]. At latitudes varying from the equator to slightly north and south of latitude 50^0, from sea level to over 3000 meters elevation, under heavy rainfall and semi-arid conditions, cool and very hot climates[4,5]. Maize being a C4 plant has higher grain yield and wider adaptation over wide range of environmental conditions so it is physiologically more efficient[6]. It is cultivated worldwide in an area of 159 million hectares with a production of 796.46 million metric tons, Maize production in Africa was estimated to be 41.6 million metric tons of which 27.7 million metric tons is produced in sub-Saharan Africaand accounting for over 24% of the total cereal productions in Africa[7,8].

In Sudan, the crop plays a great role in food security for the people in Blue Nile and South Kordofan States[9]. However, promising cereal crop with the potential usefulness for both human beings about 67% and livestock 25%, its ranks the fourth important cereal crop in Sudan after sorghum, wheat and pearl millet. Although is emerging as an important cereal crop in Sudan, the vast majority of farmers still practice recycling seeds of open pollinated varieties (OPVs) without continuous maintenance measures[10,11] and maize is considered a minor crop and it is normally grown in Kordofan, Darfur and Southern States or in small irrigated areas in the Northern states, with average production of about 0.697 ton/ha[12].

An assembling of the new varieties requires basic population that has a high genetic diversity which can be obtained through the introduction, cross over, genetic transformation and mutation[13]. Genetic variability can also be increased by inducing mutations with ionized radiations[14]. The use of nuclear techniques directed for inducing mutations is one of the most important ways to achieve the objective and their use has become an established technology for breeding of new varieties[15]. In this context, numeric or structural chromosome rearrangements, natural or induced, constitute potential source of amplification of genetic variability and the establishment of new genetic groups[16]. Nuclear techniques, in contrast to conventional breeding techniques, are widely applied in agriculture for improving genetically diversity. Unlike conventional breeding procedures which involve the production of new genetic combinations from already existing parental genes, nuclear technology causes exclusively new gene combinations with high mutation frequency. Basic tool of nuclear technology for crop improvement is the use of ionizing radiation which causes induced mutations in plants. These mutations might be beneficial and have higher economical values[17].

Maize has been a keystone model organism for basic research for nearly a century. Within the cereals, which include other plant model species such as rice (*Oryza sativa*), sorghum (*Sorghum bicolor*), wheat (*Triticum*spp.) and barley (*Hordeumvulgare*), maize is the most thoroughly researched system. As a model organism, maize is the subject of far-ranging biological investigations such as plant domestication, genome evolution, developmental physiology, epigenetic, pest resistance, heterosis, quantitative inheritance, and comparative genomics[18]. Kharkwal and Shu reported that more than 2700 officially released mutation varieties form 170 plant species and more than 60 countries[19]. Over 1000 of them major staple crop, over 60 countries, resulting in the annual treatment of 500,000 metric tons of foods in over 180 gamma radiation facilities. Almost 89% of mutant varieties developed by using of physical mutagens and about 60% of them were created by applying gamma ray mutants at cereal crops caused to product high yield, resistant to mildew, strong stem, high protein and skinless seeds. Hence the objectives of this study were to study mutation induction of different doses on maize genotypes to determine the optimum dose of gamma radiation among the studies genotypes.

Materials and Methods

Plant material and irradiations treatment

The plant material used in this study consisted of four OPVS (open pollinated varieties) local maize (*Zea mays* L) open pollinated varieties. These varieties were var-113, Hudiba -1, Hudiba-2 and Mug45.

The laboratory experiments

The seeds of these varieties were subjected to four doses of gamma irradiation rays (0.00, 50, 100, 150 and 200GY) at the laboratory of the Sudan Atomic Energy Center, Khartoum Sudan by using ^{60}CO irradiation. These experiments were conducted at the laboratory of Agricultural Research Corporation (ARC), Wad Medani, and Sudan. Samples of 50 seeds from any treated varieties were sown in pots filled with sandy soil, these pots were irrigated and then the flowing parameters were measured.

The germination (%) was measured after 3 days from emergence of the seeds at each pot by counting the number of emergent seeds.

The shoots length was measured after 15 days from the sowing date from surface of the soil to the node of last fully expended leaf the shoot length in mean of the emerged seedlings at any pot.

The root to shoot ratio was counted after 15 days from sowing date, it was calculated by dividing the root length over shoot for the emergent seedlings plant at any pot.

The field experiments

Two experiments were conducted in season 2014 at two locations, the first in Gezira Research Station, Wad Madeni, (latitude 14-24^{0}N longitude 33-29^{0}E and 407m above sea level).The soil type of this location is central clay plains soil, characterized by its heavy cracking clays. It's also described as high calcareous alkaline soil with PH of 8.3 and low organic matter content (0.02%). The second site was the demonstration farm, (College of Agricultural Studies, Sudan University of Science and Technology- (Shambat) (15-40^{0}N longitude 32-33^{0}E and 280m above sea level). The climate of this location is described as tropical semi arid, maximum temperature is above 40^{0}C in the summer is around 20^{0}C in the winter season. The relative humidity ranges between (14-27%), during dry season, and 31-51% in wet season.

The layout of the field experiment

The experiments were laid out in a randomized complete block design (RCBD) with three replicates. The land was prepared by using disc plow, disc harrow and then ridged. Sowing date in all locations was the first week of July. The plot size was maintained two rows x 5m long and 0.8 meter between rows. The three seeds per hill were sown in inter row spacing 25 cm between holes, and then thinned to one plant per hill. All cultural practices were applied as recommended by (ARC), Agricultural Research Corporation for maize production.

All treated varieties with the different irradiation doses were sown in the experimental field of the two locations. The data were collected on the four varieties treated with two doses (zero and 50GY) due to failure of the germination of the other doses. Data were recorded flowing growth and yield traits such as days to 50% flowering (tasseling and silking), plant height (cm), number of row per ear, number of kernels per row, ear diameter (cm),kernel weight (g) and grain yield (kg/ha).

Statically Analysis

Analysis of the variance was carried out on data collected used Statistical analysis system (SAS) computer package to detected differences among the treatments and the means compared by Duncan's Multiple Range Test (DMRT) at both level 0.05 and 0.01.

Results and Discussion

The effect of gamma irradiation for laboratory tests

Germination (%)

The obtained laboratory results for estimating of the germination percentage revealed that the growth of the genotypes was decreased with the increasing of the gamma doses, therefore, genotype Hudiba-1 obtained the highest percentage (81.4%)compared with the control, whereas the genotypes Mug45 and Hudiba-2 obtained the lowest percentage (6.6 and 6.4 %) respectively, for 200GY which were presented in figure 1.

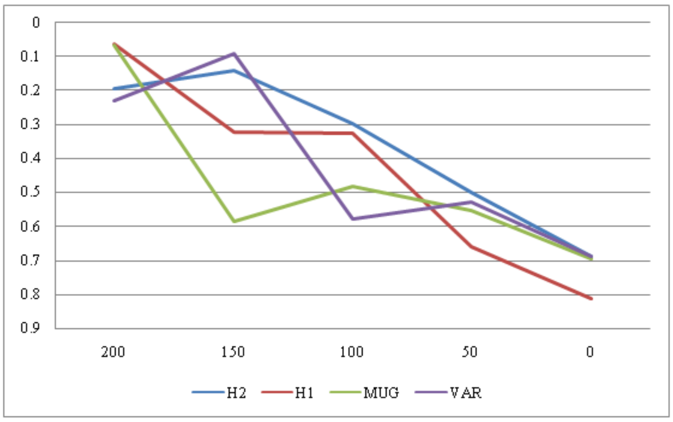

Figure 1: Germenation % for the seedlings of the four genotypes of maize treated with different doses of gamma rays

These results were similar with the findings of Yadav (2014) and Ajay (1989), who reported the germination % for the different maize genotypes was deceased with the increasing of gamma doses[20,21].

The length of shoot, root and shoot root ratio

The results were presented in figures 2, 3, 4 and 5, revealed that shoot and root lengths of the seedlings of the four genotypes were decreased with the increasing of gamma irradiation doses. There's a variation of response between subjected cultivars, the highest shoot and root ratios were (26.4 cm and 15.0cm) was obtained by Hudiba-2, respectively. The higher lengths obtained by dose 50GY were relatively higher than the control (26.2 and 13.0cm) in contrast lowest lengths were obtained by a doses of 150GY, (10.3 and 7.8ncm) (Figure 2) respectively. The tested varieties revealed a different response to irradiation doses , therefore, Hudiba-1 obtained a highest shoot and root ratios of (23.3 and 14.5cm) in a dose of 50GY, and the lowest lengths in dose 150GY, (3.9 and 5.3 cm) compared with control (24.9 and 16.3cm) (Figure 3). The irradiation dose 200GY did not survive further investigations in both genotypes (Hudiba-1 and Hudiab-2) respectively.

The second tested genotype Mug 45 having highest shoot and root ratios (25.6 and 14.8cm) in a dose of 50GY, and the control (25.6 and 11.5 cm), and the lowest lengths were (15.8 and 7.7cm) obtained by the dose (100GY) as the presented in (Figure 4). As the same results obtained by genotype VAR 113,by using dose of 50GY (21.5 and 13.5 cm) compared with the control obtained (24.4 and 19.1 cm), generally, the lowest lengths (7.9 and 5.2 cm) were give by a dose of (100GY) (Fig-5). The doses 150 and 200GY appears dominated lethality in Mug45 and Var-113), showed in (Figure 4 and Figure 5). These results in agreement with Emrani et al. studied the effect of the different doses of irradiation in two maize cultivars, the results were shown that the root and shoot of both cultivars were decreased with the increasing irradiation of the doses up to 400 and 600 GY[22].

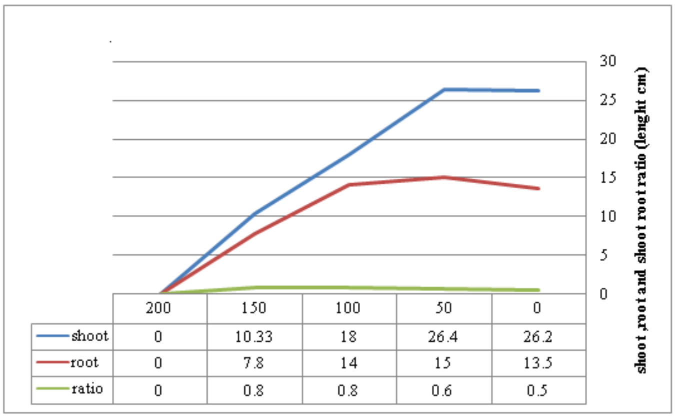

Figure 2: Determent the shoot and root ratios for the seedlings of the maize genotype Hudiba-2 treated with the different doses of gamma irradiation

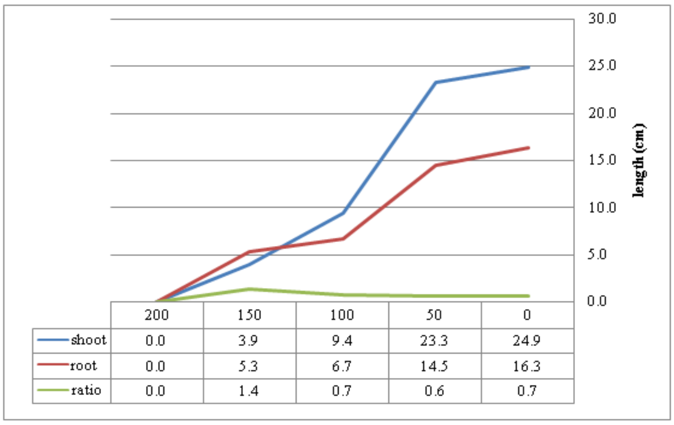

Figure 3: The shoot and root ratios for the seedlings of the maize genotype Hudiba-1 treated with different doses of gamma irradiation

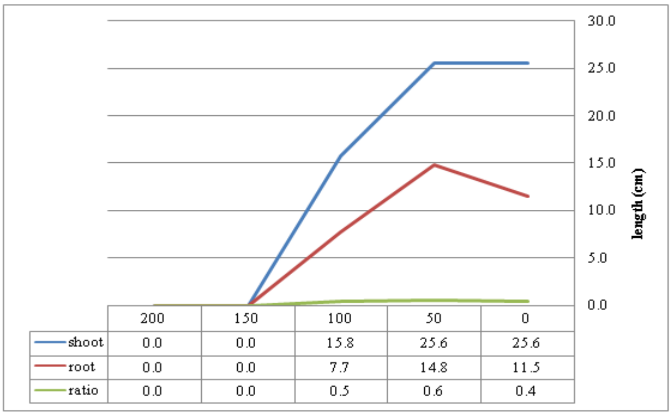

Figure 4: Determent of shoot and root ratios for the seedlings of the genotype Mug45 treated with different doses of gamma irradiation

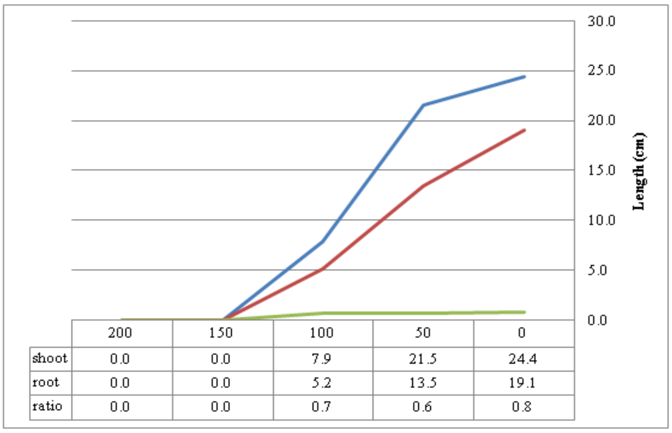

Figure 5: Determent on shoot and root ratios for seedling maize genotype Var-113treated with different doses of gamma irradiation

The effect of gamma irradiation of the field experiments

Shambat site: The statistical analysis of variance revealed that there was significant difference between the two doses of irradiation (control and 50 GY dose), for the days to silking and silking, number of rows and 100 kernels weight (Table 1.a) respectively, also there were non-significant differences for the genotypes for all studied traits as presented in table (1.b).

Table (1.a): The means effects of gamma irradiation on doses (0.0 and 50GY) on maize genotypes traits performance at Shambat farm season 2014

	Control	Dose 50 GY	Means	C.V %	F-value
Days of tassaling	49b	53a	51	7.6	5.8*
Days of silking	51b	56a	53.5	6.4	9.3**
Plant height (cm)	100.6a	92.4a	96.5	16.1	1.6ns
Ear diameter (cm)	2.7a	2.8a	2.7	22.4	0.4ns
Number of rows/ear	11a	10a	10.5	12.7	4.2ns
Number of rows	16a	13b	14	28.8	3.9*
100 kernel weight (g)	15.6a	17.4a	16.5	13	3.9*
Grain yield (k/ha)	1540a	1423.2a	1481.5	37	0.27ns

H2= Hudiba-2, H1= Hudiba-1, MUG= Mugtama-45 and VAR=Var-113 Respectively.

Table (1.b): The means of effects gamma irradiation for studied genotypes on the growth performance traits in Shambat season 2014

	VAR	HU1	HU2	MUG	Means	C.V.%	F-value
Days of tassaling	51.1 a	49.8a	51.8a	a51.1	51	7.6	0.28 ns
Days of silking	54a	52.1a	54.5a	53.3a	53.5	6.4	0.51 ns
Plant height (cm)	93.8a	a94.7	100.2a	a97.3	96.5	16.1	1.63 ns
Number of cob	12a	14a	12.5a	11.6a	12.5	23.6	0.73
Ear diameter (cm)	2.6a	2.5a	3a	2.7a	2.7	22.4	1.11ns
Number of rows/ear	11a	11a	10.6a	10.6a	10.8	12.7	0.12ns
Number of rows	14.6a	15a	14.6a	a13.1	14.3	28.8	0.23ns
100 grain weight (g)	15.9a	16a	17a	16.4a	16.5	13	1.11ns
Grain yield (k/ha)	1125.6a	1552.9a	1537.6a	1711.3	1481.5	37	1.24ns

H2= Hudiba-2, H1= Hudiba-1, MUG= Mugtama-45 and VAR=Var-113 Respectively.

On the other hand the interactions between the two doses and the genotypes of maize, the results were showed that there was significant at (p<0.01) for 100 kernel weight and non-significant difference for other traits (Table 1.c).

Table (1.c): The means of effects gamma irradiation interaction for studied genotypes on the growth performance traits in Shambat season 2014

	Control (0.0)				Dose 50 GY					doses
	VAR	Hu1	H2	Mug	VAR	Hu1	H2	Mug	C.V %	F. value
Date of tassaling	45	47	46	45	48	49	48	47	37**	2.4
Date silking	48	50	48	48	51	53	51	50	31**	2.8
Plant height (cm)	148	167.6	160	159.8	140.6	139.3	150.1	154.7	8.2*	7.4
Ear diameter (mm)	3.4	3.3	3.4	3.6	3.3	3.5	3.4	3.4	0.1 ns	7.2
Number of rows/ear	13.3	15.3	15	13.3	13.6	13.3	14	14.5	1 ns	7
Number of rows	33.6	31	30.6	34.6	28	31.6	28.3	27.5	9.8**	8.6
100 grain weight (g)	19.5	19.2	18.3	20.6	22.5	20.1	21.5	23.2	3.9ns	13.4
Grain yield/hectare	983	917	929	1182	922	1021	918.6	1003	0.3 ns	17.2

H2= Hudiba-2, H1= Hudiba-1, MUG= Mugtama-45 and VAR=Var-113 Respectively.

The number100 kernels weight was give a highest value was (18.6) and (20.1 g), obtained by Hudiba-1 and Hudiba-2 and in the control (0.00), and the lowest value was (11.9) obtained by Hudiba-1, in the control (0.00). These results were in agreement with[23], who reported that ear weight husked, ear weight dehusked, dry ear weight, weight of kernel/ear characters were decreased with the increasing of gamma irradiation doses.

Breeding programs in maize and other economical crops aim to exploit the existing variability and to enhance genetic variability[24]. Selection of the suitable mutagenic treatment is another way for existing variability than can be used in any successful breeding program[25]. Similar findings of this study existing variability in maize by using gamma irradiation were reported by Rafinddin et al.[26]. This variability could be of great value in any maize breeding program.

Medani site

The analysis of variance in Medani site was showed that there were a significant differences at (p<0.01) between the two doses of irradiation (control and 50GY dose) for the days to 50% tasseling, silking and number of rows and plant height as presented in (Table 2.a). But the grain yield was decreased in the dose 50GY which compared with the mean of the control (962.9-1003 kg/ha), and the overall mean (983.8 kg/ha) respectively. Reduction of the grain yield due to sterility of the pollen grain and the kernel set (dominant of lethality doses)[27].

The results also appears that there were non-significant different between the four genotypes for all characters except days to 50% tasseling and silking.

Table (2.a): The means effects of gamma irradiation doses (0.0 and 50 GY) on maize traits performance in Medeni season 2014

	Control	Dose 50GY	Means	C.V%	F-value
Date of tassaling	45.9b	48.2a	47	2.4	37**
Date of silking	48.8b	51.5a	50.1	2.8	31**
Plant height (cm)	159a	145.4b	152.5	7.4	8.2*
Ear diameter (cm)	3.4a	3.4a	3.4	7.2	0.1 ns
Number of rows/ear	14.2a	13.8a	14	7	1 ns
Number of rows	32.5a	29b	30.8	8.6	9.8**
100 kernel weight (g)	19.4a	21.7a	20.5	13.4	3.9ns
Grain yield (k/ha)	1003a	962.9a	983.8	17.2	0.3 ns

Interaction between the two doses of irradiation and the genotypes revealed that there were significant at ($p<0.05$) for the ear height, number of cob and the number of rows /ear, where as non-significant different for the other characters (Table 2.c). For plant height, the highest value (167.6cm), was obtained by Hudiba-1 in (o dose) control, but in 50GY the lowest value (139.3cm) obtained by the Hudiba-1.

Table (2.b).The means effects of gamma irradiation of four genotypes of maize on growth traits performance in Medeni season 2014

	Var-113	HU1	HU2	MUG	Means	C.V.%	F-value
Date of tassaling	46.5b	48.3a	47.1ab	46b	47	2.4	4.3*
Date silking	49.5b	51.8a	50b	49b	50.1	2.8	1.4*
Plant height (cm)	144.6a	155.1a	157.8a	152.5a	152.5	7.4	1.4 ns
Ear diameter (cm)	3.3a	3.4a	3.4a	3.5a	14.2	7.2	0.3 ns
Number of rows/ear	13.5a	14.3a	14.5a	13.8a	3.4	7	1.3 ns
Number of rows	30.8a	31.3a	29.5a	31.8a	14	8.6	0.7 ns
100 kernel weight (g)	21a	19.6a	19.9a	21.6a	30.8	13.4	0.6 ns
Grain yield (k/ha)	952.5a	969a	1110.a	983.8a	20.5	17.2	0.3 ns

H2= Hudiba-2, H1= Hudiba-1, MUG= Mugtama-45 and VAR=Var-113 Respectively.

Table (2.c) the effects of gamma irradiation doses on genotypes at Medeni season 2014 (general)

	Control (0.0)				Dose 50 GY				doses	
	VAR	Hu1	H2	Mug	VAR	Hu1	H2	Mug	C.V %	F. Value
Date of tassaling	45	47	46	45	48	49	48	47	37**	2.4
Date silking	48	50	48	48	51	53	51	50	31**	2.8
Plant height (cm)	148	167.6	160	159.8	140.6	139.3	150.1	154.7	8.2*	7.4
Ear diameter (mm)	3.4	3.3	3.4	3.6	3.3	3.5	3.4	3.4	0.1 ns	7.2
Number of rows/ear	13.3	15.3	15	13.3	13.6	13.3	14	14.5	1 ns	7
Number of rows	33.6	31	30.6	34.6	28	31.6	28.3	27.5	9.8**	8.6
100 grain weight (g)	19.5	19.2	18.3	20.6	22.5	20.1	21.5	23.2	3.9ns	13.4
Grain yield/hectare	983	917	929	1182	922	1021	918.6	1003	0.3 ns	17.2

H2= Hudiba-2, H1= Hudiba-1, MUG= Mugtama-45 and VAR=Var-113 Respectively.

Table (3.a): The means effects of the gamma irradiation combined between Shambat and Madeni locations Maize growth performance season 2014

	Var113	HU1	HU2	MUG4	Means	C.V%	F-value
Date of tassaling	48.8a	49a	49.5a	49a	49.1	6.6	0.08ns
Date of silking	51.7a	52a	52.2a	51.7a	51.9	5.7	0.08ns
Plant height (cm)	119.2a	124.1a	127.7a	128.1a	124.7	10.7	1.13ns
Ear diameter (cm)	3a	2.9a	3.2a	3a	3	11.4	0.9ns
Number of rows/ear	12.2a	12.6a	12.5a	12.1a	12.4	9.7	0.5ns
Number of rows	22.7a	23.1a	22a	22.1a	22.5	15.3	0.26ns
100 grain weight (g)	18.4a	17.8a	18.9a	18.5a	18.4	13.5	0.4ns
Grain yield (k/ha)	1039.1a	1260.5a	1230.9a	1376a	1226.5	33.5	1.4ns

H2= Hudiba-2, H1= Hudiba-1, MUG= Mugtama-45 and VAR=Var-113 Respectively.

For date of tasseling the highest value (49), was obtained by the variety Hudiba-1, in the 50GY dose and the lowest value (45) was obtained by the variety Var-113, in the control. In contrast the days to silking having the highest value was (51) by Hudiba-2 and Var-113 in 50 GY dose and the lowest was (48) obtained by the Var-113, Hudiba-1 in the Control and Mugtama- 45 in a dose of 50GY.

Some other ear characteristic such as number of rows the highest value (34.6) were obtained by the Mugtama- 45in the control (0.00) and (27.5) in the 50GY dose, generally, these results similar to Yang et al. observation[28], who reported that, number of rows/kernel, 100 kernel weights, number of rows/ear decreased with the higher doses 200 GY.

Table (3.b): The means effects of the gamma irradiation combined between Shambat and Madeni locations Maize growth performance season 2014

	Dose 0 GY (Control)				Dose 50 GY				doses	
	VAR	Hu1	H2	Mug	VAR	Hu1	H2	Mug	C.V %	F. value
Date of tassaling	46.3	48.9	47.5	47.1	51.3	49.1	51.1	50.9	6.6	0.8ns
Date silking	49.3	51.4	49.8	49.6	54.1	52.5	54.6	53.8	5.7	1.0ns
Plant height (cm)	123.6	131.1	134.4	130	114.7	117	120.9	126.1	10.7	0.5ns
Ear diameter (mm)	3.1	2.8	3.1	3.1	2.9	3.1	3.2	3	11.4	0.9ns
Number of rows/ear	12.3	13.4	13.6	11.8	12.1	11.8	11.5	12.5	9.7	1.6ns
Number of rows	24.1	24.5	24.3	23.9	21.3	21.8	19.8	20.3	15.3	1.05ns
100 grain weight (g)	17.6	15.5	18.4	18.5	19.3	20.1	19.3	18.5	13.5	1.7ns
Grain yield/hectare	1223	1209	1295	1332.	921.8	1318	1292	828.1	33.5	0.6ns

H2= Hudiba-2, H1= Hudiba-1, MUG= Mugtama-45 and VAR=Var-113 Respectively

Table (3c): the means effects of gamma irradiation doses combined between Shambat and Medanilocations Maize growth performance season 2014

	control	Dose 50GY	Means	C.V %	F-value
Date of tassaling	47.5b	50.7a	49.1	6.6	11.7**
Date of silking	50b	53.7a	51.9	5.7	18.7***
Plant height (cm)	129.8a	119.7b	124.7	10.7	6.7*
Ear diameter (cm)	3a	3.1a	3	11.4	0.08 ns
Number of rows/ear	12.8a	12b	12.4	9.7	5.6*
Number of rows	24.2a	20.8b	22.5	15.3	11.6**
100 kernel weight (g)	17.5b	19.3a	18.4	13.5	6.1*
Grain yield (k/ha)	1271.5a	1181.6a	1226.5	33.5	0.5 ns

H2= Hudiba-2, H1= Hudiba-1, MUG= Mugtama-45 and VAR=Var-113 Respectively.

Conclusion

Based on the results obtained from this study, it could be conducted that, the gamma rays have negative effect on the germinations of the seedlings of maize genotypes. The increasing of the gamma irradiation decreased the growth of the germination. The genotypes treated with the high doses (150-200GY) were germinated but they failed to survive after 10 days from their germination. In addition the dose 200GY failed in the two locations, therefore, the suitable dose was 50 GY in both lab and field condition.

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