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Effect of Gamma Irradiation of Seeds on the Development and Productivity of Three Maize Varieties (*Zea mays*. L) in Côte D'ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AK, YKFK, SD and KYJ designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KK, KAB and YKFK managed the analyses of the study. Author YKFK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Climate variability has been and continues to be the main source of food fluctuations. This variability threatens the production of cash crops such as maize (*Zea mays* L). Maize is a cereal and has become one of the main agricultural crops in Côte d'Ivoire. The objective of this study is to determine the agro-morphological characteristics of three (03) varieties of maize (EV 8728, GMRP / 18 and MDJ) which have undergone irradiation with gamma radiation (0, 100, 200 and 300 grays) to induce mutations. The agro-morphological evaluation was carried out in a completely randomized block device. morphological characters selected from the descriptors of maize were used in this study. The descriptive analysis revealed a significant diversity between the treatments. The comparison between all the agro-morphological characters and the different treatments showed that the treatments EV8728_0 and EV8728_100 Gy had the best characteristics of ears and grains and the treatment MDJ_200 had the best vegetative characteristics.

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1. INTRODUCTION

The various economic, financial, oil and food crises have caused undernourishment in the world today of about 925 million people [1]. In its fight against hunger, the FAO has shown that 35 countries in the world, including 28 African countries, need external food aid. Hence, food security has become one of the biggest development challenges for African countries, including Côte d'Ivoire [2]. Ivorian agriculture, which used to be a lever for its economic development, was based on coffee and cocoa growing, supported by subsistence farming such as rice (Oriza sp), corn (*Zea mays* L.), yam (Discorea sp), cassava. (*manihot esculenta*) and plantain (Musa sp) to ensure food self-sufficiency. Today, the demand for certain food products coupled with the increase in the population is growing, especially that of corn. Corn is the most energetic cereal, rich in starch, protein and minerals [3]. Economically, corn is a source of income for farmers [4]. Corn is also used for human and animal food (poultry, pigs, cattle) and is used as a raw material in certain industries such as brewing, oil and soap making [5]. Corn is grown all over Côte d'Ivoire with three main areas which provide 68% of the country's total crop production. These are the Savannah regions with 49.78%, Haut Sassandra with 9.27% and Denguelé with 8.79% (DSDI / MINAGRI, 2010). National production is estimated at 661,285 tonnes, for a total land area of 327,800 ha, or 1.9 $t.ha^{-1}$ [6].

For several improvement decades, yield increases are more due to area extension than maize productivity. In addition, there is a drop in production compared to cultivated land, due to global climate change which results in delays and irregularities in precipitation; more marked and / or more frequent drought periods; genetic degeneration of cultivated varieties; loss of soil fertility; increased frequency of paroxysmal phenomena and abnormal events [7]. Faced with these difficulties, many solutions are sought around the world, among which the use of fertilizers without success due to the high cost of these fertilizers, the introduction of high-performance varieties often poorly adapted to the pedoclimatic and economic requirements, the creation of varieties.

In order to contribute to finding improved varieties of corn that respond durably to climatic variability and the loss of soil fertility, the research program on the development of corn varieties adapted to the soil and climatic conditions of northern Côte d'Ivoire in the context of climate change by the techniques of induced mutation was initiated by the University Jean Lorougnon Guédé (UJLoG). The objective of this study was to study the agro-morphological characteristics of three (03) varieties of corn (EV 8728, GMRP / 18 and MDJ) which have each undergone irradiation with gamma radiation (100, 200 and 300 grays) to induce mutations.

2. MATERIALS AND METHODS

2.1 Study Site

The study site is that of the Jean Lorougnon Guédé University, Daloa, Côte d'Ivoire. The city is located in the Haut Sassandra region in Central West of Côte d'Ivoire between 6° and 7° North latitude and 7° and 8° West longitude. The department of Daloa is bounded in the North by the departments of Vavoua and Zuenoula, in the South by those of Issia and Sinfra, in the West by the departmental districts of Duekoué and Bangolo and in the East by that of Bouaflé. The soils of the Daloa region are mainly ferralitic (typical) of granitic origin, moderately to weakly denatured and have good agricultural aptitudes for all types of crops [8].

2.2 Plant Material

The plant material used consists of corn seeds from the National Center for Agronomic Research (CNRA). These seeds, from three (3) varieties of early cycle corn (85 -95 days), underwent gamma irradiation at different doses (100 grays, 200 grays and 300 grays) at Seibersdorf in Austria, in order to induce mutations. The characteristics of the seeds used are listed in Table 1.

2.2.1 Experimental

The experimental design was a completely randomized block (RCB) with four replications. Each block included twelve elementary plots. Each plot carried a variety at an irradiation level. The dimensions of the basic plot are 5 m x 4 m.

Table 1. Characteristics of seeds

variety	Type	Color	Texture	Potential yield (t/ha)	Radiation dose (Gy)
MDJ	Improved	Yellow	Corné	3-5	100
					200
					300
EV 8728	Improved	Dark Yellow	Semi-toothed	4-5	100
					200
					300
GMRP-18	Enhanced	Light Yellow	Horny	4-5	100
					200
					300

Source: CNRA, 2006

2.2.2 Fertilization

A basic fertilization with NPK (15-15-15) was applied at 200 $kg.ha^{-1}$ 14 days after sawing and a complementary100 $Kg.ha^{-1}$ urea was added.

2.2.3 Seedling

The sowing was carried out on August. It has been done in line with two seeds per pocket at a depth of 2-3 cm and at a spacing of 1 m x 0.25 m, giving a density of 40,000 seed / ha. The emergence date was measured as the number of days between sowing and germination of 50% of the seeds.

2.2.4 Observations

The measurements were carried out on a population of 14 plants randomly selected from each elementary plot, a total of 56 plants per dose. Fifteen parameters classified into two groups, were determined in this work:

- vegetative parameters: the date of emergence (50 % germination), the height of the plant, the diameter of the plant at the collar, the number of sheets.
- production parameters: the number of ears per plant, the weight of the ear without the husks, the number of grains per ear and the grain yield. The harvest was done on the 120th day after sowing. The fresh yield is calculated according to the formula:

$$\frac{\text{Weight of grain harvested (t)}}{\text{area (ha)}} \times 10$$

2.2.5 Data analysis

Data were entered with Excel 2013 software and the statistical analysis data were carried out with the R 3.1.3. An ANOVA was performed to determine the variability between the observed values. Means ranking was carried out by the Duncan test at the 5 %.

3. RESULTS AND DISCUSSION

3.1 Results

The results of our work relate mainly to the lifting, the height, the diameter, the number of leaves and the number of nodes for the vegetative phase. Then, the number of ears per plant, the mass of the ear without the spathes, the number of grains per ear, grain mass per ear and grain yield for production parameters.

3.1.1 Effect of radiation dose on emergence

The first emergence was observed three days after sowing (JAS) for each variety and for all doses. By the 4th day, more than 50% of the seeds have germinated. The cumulative emergence rate recorded at 13 days after sowing (Table 2), showed that the germination power of the grains was not affected at 100 Gy (82.2%) and 200 Gy (80%) irradiation doses while the 300 rusuce that germination rate. However, the variety EV8728 showed the lowest emergence rate (74%) against 79.3 and 80.5% respectively in GMRP / 18 and MDJ.

3.1.2 Growth and development parameters

3.1.2.1 Effect of the irradiation dose on the height of the plants

The plant growth in height is illustrate in Fig. 1 according to the irradiation dose. It shows that plant growth started up to the 5 th with. Than it was accelerate from the 5 th to 8 th weak after. Over the 8 th was, the plants height became plant height seemed to be function of the irradiation dose. Indeed, 300 gy affered smaltiste plants

(138 -155 cm). The analysis of variance shows a highly significant difference ($p < 2e^{-16}$; $\alpha = 0.05$) for all dose-variety combinations. It also appears that the difference observed between the varieties studied for the dose 300 Gy and the other doses is highly significant ($p < 2e^{-16}$; $\alpha = 0.05$) (Table 3). Ranking the means with the Duncan Test at the 5 % threshold shows that the varieties studied behave differently according to the doses. So, the greatest height is observed in MDJ_200 and MDJ_0 with respectively 233.9 cm and 232.4 cm and the lowest heights in MDJ_300, EV8728_300 and GMRP / 18_300 with 166.36 cm, 154.64 cm and 138.14 cm respectively (Table 4).

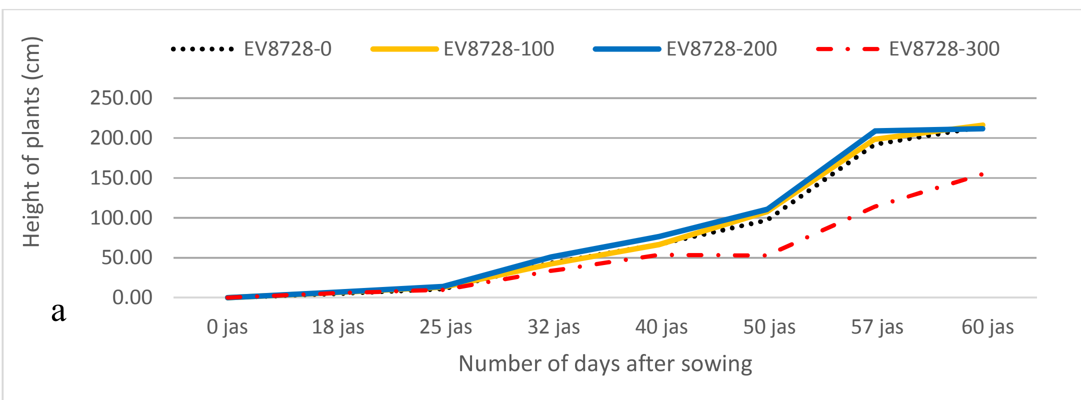
3.1.2.2 Effect of the irradiation dose on the diameter of the plants

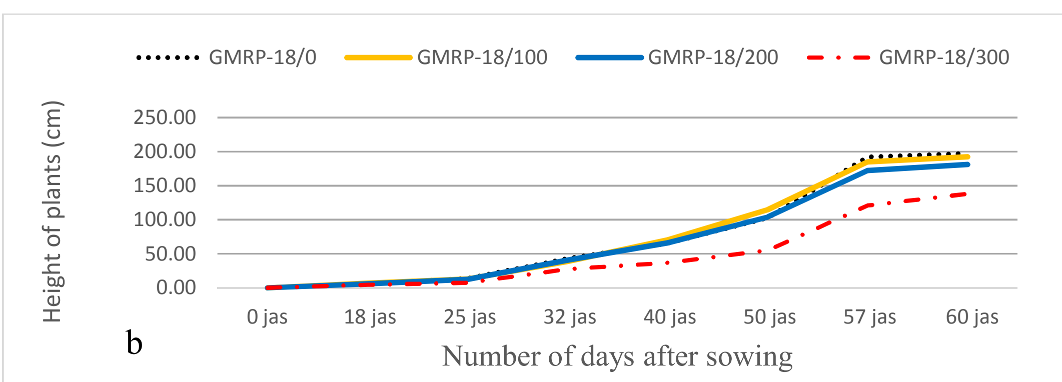
The plant diameter was measured and variation is Table 5. In general, the diameter increases rapidly from the 15th to the 48th day after sowing. Then, it becomes stationary, with a slight regression for doses 300 gy. The results of the analysis of variance revealed a highly significant difference ($p < 2e^{-16}$; $\alpha = 0.05$) of the different doses on the expression of the diameter (Table 3). Duncan test shows that lower values are at the dose level 300 (EV 8728_ 300: 1.65 ± 0.00, MDJ_ 300: 1.61 ± 0.00 and GMRP / 18_ 300: 1.59 ± 0 ,00) (Table 4).

Table 2. Variation in the cumulative emergence rate of maize varieties at 13 days after sowing

Variety	EV8728				GMRP/18				MDJ			
Radiation dose (Gy)	0	100	200	300	0	100	200	300	0	100	200	300
Germination rate 13 JAS in %	83.25^{a}	82.25^{a}	73^{b}	66.75^{bc}	78^{b}	84.25^{a}	81.5^{a}	72.25^{bc}	84.25^{a}	80^{ab}	85.5^{a}	76^{b}

NB: The values affected by the same letter, in the same column are not significantly different at the 5% threshold





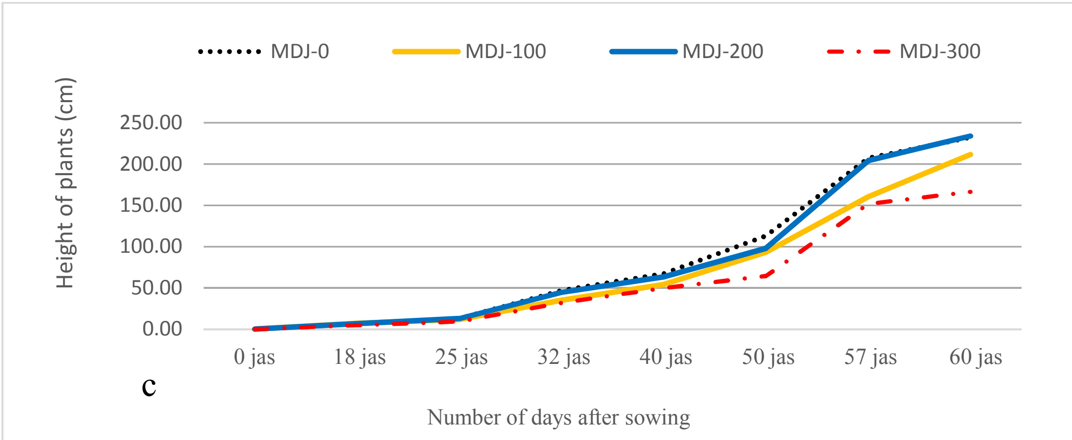


Fig. 1. Effect of the gamma ray dose on height growth of three varieties of corn
a. EV 8728 b. GMRP-18 c. MDJ

Table 3. Analysis of variance for growth parameters

Settings		Df	SumSq	MeanSq	F value	Pr (>F)
Plants height	Blocks	3	1	0.3	0.7924	0.5068
	Treatments	11	41143	3740.2	9026.736	$< 2e^{-16}$
	Résiduals	33	14	0.4		
Plants diameter	Blocks	3	0	0	$8.09\ e^{-01}$	0.4978
	Treatments	11	0.57067	0.051879	$4.25\ e^{+28}$	$< 2e^{-16}$
	Résiduals	33	0	0		
Number of leaves / plant	Blocks	3	0.0124	0.00414	0.3494	0.7898
	Treatments	11	13.8585	1.25986	106.4285	$< 2e^{-16}$
	Résiduals	33	0.3906	0.01184		
Number of nodes / plant	Blocks	3	0.004	0.0014	0.0584	0.9812
	Treatments	11	83.979	7.6344	321.9353	$< 2e^{-16}$
	Résiduals	33	0.783	0.0237		

Table 4. Variation of the components of the growth and development of the varieties according to the different doses of gamma ray irradiation

Treatments	Height of plants	Diameter of stem	Number of plants	Number of nodes
EV 8728_ 0	214,14±0,00 d	1,87±0,00 a	12,86±0,00 c	11,14±0,00 c
EV 8728_ 100	216,29±0,00 c	1,79±0,00 d	13,00±0,05 bc	11,45±0,02 b
EV 8728_ 200	211,53±0,21 e	1,68±0,00 g	13,12±0,11 b	11,59±0,18 b
EV 8728_ 300	154,64±0,00 j	1,65±0,00 h	12,21±0,00 g	9,50±0,00 e
GMRP/18_ 0	197,00±0,00 f	1,74±0,00 e	12,50±0,07 de	11,89±0,12 a
GMRP/18_ 100	192,14± 0,00 g	1,52±0,00 l	12,43±0,00 ef	9,85±0,29 d
GMRP/18_ 200	181,00±0,00 h	1,57±0,00 k	12,30±0,25 fg	11,18±0,21 c
GMRP/18_ 300	138,14±0,00 k	1,59±0,00 j	11,21±0,14 h	7,71±0,00 g
MDJ_ 0	232,43±0,00 b	1,84±0,00 b	12,46±0,11 ef	11,92±0,10 a
MDJ_ 100	214,97±2,20 d	1,69±0,00 f	13,32±0,12 a	11,19±0,16 c
MDJ_ 200	233,93±0,00 a	1,81±0,00 c	13,07±0,00 b	12,00±0,00 a
MDJ_ 300	166,36±0,00 i	1,61±0,00 i	12,62±0,03 d	8,89±0,21 f

NB: The values affected by the same letter, in the same column are not significantly different at the 5% threshold

Table 5. Analysis of variance for some production parameters

Settings		Df	SumSq	MeanSq	F value	Pr(>F)
Number of ears / plant	Blocks	3	0.21588	0.071961	4.1052	0.0139805
	Treatments	11	0.81765	0.074332	4.2404	0.0006024
	Résiduels	33	0.57847	0.017529		
Mass of ear without spathes	Blocks	3	17688	5896	20.18	$1.309e^{-07}$
	Treatments	11	47486	4316.9	14.775	$9.314e^{-10}$
	Résiduals	33	9642	292.2		
Number of grains / ear	Blocks	3	17527	5842	2.6599	0.06429
	Treatments	11	525318	47756	21.742	$5.019e^{-12}$
	Résiduals	33	72484	2196		
Grain / ear mass	Blocks	3	7167	2389	11.094	$3.432e^{-05}$
	Treatments	11	35647	3240.6	15.049	$7.332e^{-10}$
	Résiduals	33	7106	215.3		
Grain yield	Blocks	3	8.458	2.8192	10.931	$3.866e^{-05}$
	Treatments	11	45.279	4.1163	15.96	$3.385e^{-10}$
	Résiduals	33	8.511	0.2579		

3.1.2.3 Effect of the radiation dose on the number of leaves and nodes

The leaves and nodes is influenced by the different irradiation doses irradiation. Indeed, compared to control plants, doses 100 and 200 Gy seem to stimulate leaf production in all varieties. However, at 300 Gy, the leaves number is significantly reduced (12 sheets on average). The number of nodes, also negatively influenced by all doses. This influence is very marked by irradiation the dose 300 Gy with 8.7 knots on average against 11 knots at 100 and 200 gy. Analysis of the variance confirms a very highly significant difference ($p < 2e^{-16}$; α = 0.05) in the radiation doses on the number of leaves and nodes per plant (Table 3). Duncan's Test at the 5% level revealed different dose groups for the two parameters. It also showed that GMRP / 18 produced fewer leaves and nodes than EV8728 and MDJ (Table 4).

3.1.3 Production parameters

3.1.3.1 Effect of the irradiation dose on the number of ear per plant

The number of ears per plant is influenced by the of gamma irradiation dose. Compared to the control, some doses have a stimulating action and others inhibit. So, the 100 Gy dose offers the highest number of ears per plant with 1.52 ± 0.08; 1.47 ± 0.17 and 1.47 ± 0.18 respectively for EV8728, GMRP / 18 and MDJ. The 200 Gy dose reduces the number of ears in the EV 8728 variety but increases this number in GMRP / 18 and MDJ. In contrast, the 300 gy dose produced less ear per plant with 1.10 ± 0.12 and 1.19 ± 0.14 respectively for GMRP / 18 and MDJ. Overall, Variety EV 8728 produced more ears than GMRP / 18 and MDJ. The analysis of variance showed that the number of ears had is highly significant difference for the treatment (p = 0.0006024; α = 0.05) (Table 5). The Duncan test at 5% level revealed several groups of doses (Table 6).

3.1.3.2 Effect of the irradiation dose on the ear weight

The mass of the ear without husks varied with the doses of gamma irradiation. The mass decreases significantly as the radiation dose increases. So, for all varieties combined, the mass decreased from the control (137.7 g) to 132.5 g, 100.7 g and 69.4 g respectively in the doses 100, 200 and 300 Gy. From the analysis of variance (Table 5), it appeared that the ear weight was significantly different with the irradiation dose ($p = 9.314e^{-10}$; α = 0,05). The means classification with the Duncan Test (Table 6) shows that the treatments EV 8728_0 and EV 8728_100 had the highest weight with 160.25 ± 41.00 and 151.66 ± 33.04 respectively. On the other hand, the lowest weight are obtained with the GMRP / 18_300 and MDJ_300 treatments (54.11 ± 16.43 and 63.68 ± 15.54). The behavior of the varieties with respect to the doses revealed a varietal effect.

Table 6. Variation in production components according to treatments

Treatments	Number of ears/Plant	Spike mass without spathes (g)	Number of grains / ear	Mass of grains / ear (g)	Grain yield (t.ha^{-1})
EV 8728_ 0	1,47±0,21 a	160,25±41,00 a	472,23±67,56 a	126,79±30,25 a	4,10±0,94 a
EV 8728_ 100	1,52±0,08 a	151,66±33,04 ab	447,55±50,49 a	125,21±23,89 a	4,13±0,81 a
EV 8728_ 200	1,37±0,17 ab	107,43±40,71 cd	306,78±77,13 cd	84,34±30,94 bcd	2,76±1,08 bc
EV 8728_ 300	1,32±0,14 ab	90,39±15,52 de	249,25±46,45 de	68,12±11,87 d	2,24±0,35 cd
GMRP/18_ 0	1,21±0,16 bc	127,00±25,01 bc	401,40±49,61 ab	105,62±18,65 ab	3,28±0,79 b
GMRP/18_ 100	1,47±0,17 a	123,31±28,75 bc	364,45±50,27 bc	97,78±23,37 bc	3,24±0,79 b
GMRP/18_ 200	1,31±0,07 abc	87,11±12,26 de	217,24±56,93 ef	62,49±20,64 de	1,96±0,76 de
GMRP/18_ 300	1,10±0,12 c	54,11±16,43 f	136,81±48,73 g	39,65±11,83 f	0,85±0,35 f
MDJ_ 0	1,18±0,02 bc	125,60±21,22 bc	368,17±31,19 bc	98,47±16,88 bc	3,28±0,56 b
MDJ_ 100	1,47±0,18 a	122,57±16,50 bc	370,86±25,90 bc	95,55±11,10 bc	3,18±0,36 b
MDJ_ 200	1,36±0,16 ab	107,49±23,94 cd	266,57±37,59 de	75,81±13,77 cd	2,53±0,46 bcd
MDJ_ 300	1,19±0,14 bc	63,68±15,54 ef	156,32±33,44 fg	43,35±10,65 ef	1,32±0,39 ef

NB: The values affected by the same letter, in the same column are not significantly different at the 5% threshold

Table 7. Correlation between the quantitative variables measured

	High	Diam	Nleaf	Nnode	Nears	ME-S	Ngrain	Mgrain	Yield
Hight		0,72	0,77	0,89	0,35	0,61	0,64	0,60	0,64
Diam			0,47	0,65	0,14	0,54	0,57	0,53	0,53
N. eaf				0,71	0,50	0,51	0,51	0,48	0,53
N. node					0,30	0,58	0,62	0,58	0,61
Ear						0,62	0,58	0,62	0,62
M Epi-S							0,90	0,95	0,95
N. grain								0,94	0,93
M. grain									0,99
Yield									

3.1.3.3 Effect of the irradiation dose on the number of grains per ear

The dose significantly improved the number of grains per ear. Indeed, the lost in gain number was thigh with the 200 and 300 Gy doses, at of 36.4% and 66.7% respectively. This lost in the number of grains per ear depending on the doses was found to be very highly significant (p = 5.019e-12; α = 0.05) (Table 5). According to Duncan test, there are three dose classes in the varieties EV8728 and MDJ (0 and 100 Gy; 200 Gy; 300 Gy) and four dose groups with the variety GMRP / 18 (Table 6).

3.1.3.4 Effect of the irradiation dose on the weight of grain per ear

The average grain weight per ear was affected by the gamma irradiation doses. Indeed, for varieties EV8728 and MDJ, there was no significant difference in weight between the control does and the 100 Gy doses. On the other hand, variety GMRP / 18, the control different significantly from the 100 Gy dose. Also, the other doses, for all varieties, caused a lost in the grain weight. However, this reduction is very strong with the dose 300 gy, that is to say more than 50% of reduction rate in the varieties studied accepted the variety EV8728_300 (46%). The analysis of variance qualified this difference as very highly significant (p = 7.332e-10; α = 0.05) (Table 5) between the Irradiation Doses and the mass of the grains per ear. Duncan's Test at the 5% level showed several groups of irradiation doses concerning the evolution of grain mass per ear (Table 6).

3.1.3.5 Effect of dose on grain yield

In general, the increase in radiation doses led to a decrease in the grain yield. Indeed, the corn grain yield is inversely proportional to the radiation dose. However, the difference in grain yield of the controls (an average of 3.55 $t.ha^{-1}$) is statistically not difference form that of the 100 Gy doses (an average of 3.52 $t.ha^{-1}$) for maize. The 200 and 300 Gy doses resulted in low yield production of 2.4 and 1.4 $t.ha^{-1}$ respectively. Otherwise, EV8728 produced more than MDJ and GMRP / 18 either in irradiation (3 $t.ha^{-1}$) or not irradiation conditions (3 $t.ha^{-1}$).

The results of the analysis of variance confirmed a very highly significant difference (p = 3.385 e^{-10}; α = 0.05) between the gamma irradiation doses and the expression of the yield in grain of corn varietie (Table 5). The classification of the means of the different yields with the Duncan Test at 5 % threshold revealed three groups of irradiation doses for each variety including 0 and 100 Gy (1st), 200 Gy (2nd) and 300 gy (3rd) (Table 6).

3.1.4 Correlation between measured variables

In order to establish possible relationships between the different parameters determined during this study, a correlation matrix (Pearson coefficient) was produced (Table 7). Analysis of this matrix showed that there are important correlations between height and diameter (r = 0.72), the number of leaves (r = 0.77), and the number of nodes (r = 0.89). The number of leaves and the number of nodes had a good correlation (r = 0.71). The weight of the ear without a spathe showed a strong correlation with the number of grain per ear (r = 0.90), the grain weight of an ear (r = 0.95) and the yield (r = 0.95). The number of grains is correlated with the grain weight per ear (r = 0.94) and the yield (r = 0.93). Finally, a very strong correlation was established between grain weight and grain yield (r = 0.99).

3.2 Discussion

The results relating to the vegetative parameters of our work showed several variations between the different doses of gamma irradiation and the controls. So, the emergence rate is generally around 78% for seeds irradiated. This rate is roughly equal to that of non-irradiated seeds (81.8%). Seeds treated with 100 Gy offer better emergence compared to 200 Gy and 300 Gy. However, the varieties behave differently depending on the irradiation doses. Indeed, in the Variety EV8728, the germination rate is low only for the 200 and 300 Gy doses. Similar results have been reported by Rozman [9] and Neelamegam and Sutha [10]. According to the authors, irradiations may have no effect or may increase the rate of emergence. It appears that irradiation had no effect on the germination capacity of the grains. On the other hand, in GMRP / 18, seeds irradiated at 100 and 200 Gy had higher emergence and that is agreement with Chicea and Rãcuciu [11]. The reduction in the emergence rate observed both in irradiated seeds with gamma rays and in control seeds would be due to the action of animals such as birds because the experiment took place in the field. According to Bignon [12], the germination of the grains depend solely on their reserves which are squeezed from the embryo of the seed to germinate. The results also showed that regardless of the radiation dose, the date of appearance of the coleoptiles varies from 3 to 5 days and can extend over 10 days. These results are contrary to those of Manju and Gopimony [13]. According to them, the influence of a mutagen on plant growth regulators can cause a delay in the initiation of germination of seeds going on for several days. Our results also showed that the increase in dose of irradiation reduces the germination rate of seeds. This statement is in line with the work of Hegazi and Hamideldin [14], Muralidharan and Rajendran [15] and Pushparajan et al. [16].

As for plant height, it was chosen as one of the best variables used to describe the variability of populations of cultivated corn varieties according to Louette and Smale (1996). However, the growth in length of the plants depends on the conditions of the environment (climate, humidity and temperature), and the variety. The maximum value of height is reached at flowering after a period of intense growth [17]. The structuring of the morphological diversity observed in height could result from the exposure of seeds to different doses of irradiation. The reduction in plant height for many species exposed to gamma radiation at higher doses has already been reported by Kon et al. [18]. According to Khan et al. [19], the reduction in plant height can be attributed to a reduction in mitotic activity in meristematic tissues. Higher doses of gamma radiation can have inhibitory effects on plant growth [20]. The study by Pushparajan et al. [16] showed that the mutagen has an effect on plant growth. In fact, the size of the plants decreased with the higher radiation doses. Which is in agreement with our results. Manju and Gopimony [13] also reported that the growth rate was reduced by the mutagen due to destruction of auxin. This reduction in growth rate can be explained by genetic loss due to chromosomal aberrations [16]. Ullah et al. [21] also noted a decrease in the size of okra plants due to the increased dose of gamma irradiation.

According to the work of Pushparajan et al.[16], le plus grand nombre de feuilles a été obtenu avec les lots de graines exposées à 400 Gy, tandis que les lots de graines exposées à 500 Gy ont eu le plus faible nombre de feuilles. The highest number of leaves was obtained with the seed lots exposed to 400 Gy, while the seed lots exposed to 500 Gy had the lowest number of leaves. This is in accordance with our study which showed that the irradiation doses of 100 and 200 Gy seem relatively increased the number of leaves per plant (EV8728 and MDJ) while this number was strongly reduced to 300 Gy. On the other hand, the work of, les travaux de Khan et al. [19], showed that the phyllogenic power of non-irradiated plants was much higher than that of irradiated plants whatever the dose of irradiation. Otherwise, showed that the phyllogenic power of non-irradiated plants was much higher than that of irradiated plants whatever the dose of irradiation. Otherwise, showed that the phyllogenic power of non-irradiated plants was much higher than that of irradiated plants whatever the dose of irradiation. Otherwise, showed that the phyllogenic power of non-irradiated plants was much higher than that of irradiated plants whatever the dose of irradiation. Otherwise, showed that the phyllogenic power of non-irradiated plants was much higher than that of irradiated plants whatever the dose of irradiation. Otherwise, showed that the phyllogenic power of non-irradiated plants was much higher than that of irradiated plants whatever the dose of irradiation. Otherwise, showed that the phyllogenic power of non-irradiated plants was much higher than that of irradiated plants whatever the dose of irradiation. Otherwise, Ali et al. [22] reported in their work that there was no significant difference in stem thickness growth for irradiated and non-irradiated plants. These results are contradictory to those obtained in our work.

With regard to the results relating to the production parameters, the general observation showed that the increase in the dose of irradiation with gamma rays leads to the reduction of all the parameters studied except for the parameter number of ears per plant. So, according to Khan et al. [19] mutagens stimulate the role of enzymes and hormones responsible for crop growth and yield. Our results are in line with those of Khan et al. [19] in terms of the number of ears per plant where plants from seed irradiated with gamma rays produced more ears compared to control plants. Otherwise, concerning the decrease in other parameters (mass and number of grains / ear, ear mass without husks, grain yield) with increasing doses of gamma radiation. It has been observed in the work of Pushparajan et al. [16] and Ilyas and Naz [20], a reduction in the weight of the fruit, the yield of which increases with the irradiation doses. These results confirm ours. Also, the seed lots treated with the 300 dose of the GMPR / 18 and MDJ varieties had a very low grain yield and less than one tonne. These results are similar to those of Deffan et al. [17]. The latter authors attributed this to the devastating effect of birds on the cobs before harvest.

4. CONCLUSION

At the end of our work we can remember that, Climate variability has been and continues to be the main source of yield fluctuations. This variability threatens the production of cash crops such as maize. The descriptive analysis revealed a significant diversity between the treatments, marked by a significant difference observed between the minimum values and the maximum values. The comparison between all the agro-morphological characters and the different treatments showed that the treatments EV8728_0 and EV8728_100 Gy had the best characteristics of ears and grains and the treatment MDJ_200 had the best vegetative characteristics.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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