Gamma Radiation Effects (Cs^{137}) on the Local Variety Culture of Corn (*Zea mays* L.) Under Ecological Conditions of Kenge

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ABSTRACT

The aim of the present study was to study the effects of gamma radiation (Cs^{137}) on the local variety of maize (*Zea mays* L.) usually cultivated at KENGE for possible track of its improvement. The approach consisted of irradiating the corn seeds at the doses ranging from 0 to 300 Gy at intervals of 100 each using the CONSERVATOME LISA I irradiator. The irradiated seeds were sown on a plot of 176.40 m² of surface area according to a device in completely random blocks. In the field, some cultural precautions for consequent yield have been taken (weeding, ridging at the same time as weeding, mulching, and watering). Different cultivation parameters were determined such as germination rate, crown diameter, plant size and number of leaves / maize plant from one part and, from another part, the length of the cobs, the ear diameter, number of kernels/ear, 100 kernel weights and yield per plot.

From the results obtained it turned out that the dose of 100 Gy with average values such as 67% for the germination rate, 220.80 cm for the length of the plants, 1505 seeds per plant ear and 327.25 g per 100 seeds behaved well in relation to the witness and the irradiated persons. The dose of 300 Gy gave values far lower than those of 100 Gy (19%, 67.66 cm, 713 and 90.13 g). From these analyzes, it is possible to recommend an in-depth study in the improvement of local corn with the LD50 of 169.33 Gy.

Keywords: Crop, gamma irradiation, local variety, Maize, radiosensitivity, yield.

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I. INTRODUCTION

According to FAO estimates, world food production will have to increase by 70% to feed the world population which, according to forecasts, will increase from around 7 billion to 9 billion inhabitants by 2050 [1]. It would be necessary to multiply by 1.7 the agricultural production at the world level without strong increase in cultivated areas. Increased productivity of land and conservation of natural resources cannot be achieved without addressing a multitude of issues including climate change, drought and flooding, soil erosion and salinization which all contribute to hampering the productivity of crops from land use and thus make it an increasingly risky enterprise [2].

Among the cereals cultivated in the world, maize (*Zea mays*) is among the three most cultivated cereals along with wheat and rice [3]. In East and Southern Africa, maize accounts for 41% of the area used for the cultivation of cereals and 21% in West and Central Africa [4]. The world average maize yield in temperate industrialized countries is 8.2 t / ha compared to 3.5 t / ha in tropical countries and less than 1 t / ha in part of sub-Saharan Africa. Maize is sensitive to drought at the time of flowering for two main reasons: the decreased probability of fertilization due to the lengthening of the interval between male and female flowering and the abortion of kernels due to induction, a complex mechanism induced by water deficit a few days before and ten days after fertilization [3].

The International Grains Council estimates that world maize production exceeded 1050 million tons for 2017-2018. This cereal, the most produced in the world along with wheat, barley, and rice, constitutes the bulk of the supply of the world's population [2]. The main chemical component of corn kernel is starch, accounting for 75% of its weight, itself made up of two polymers of glucose, amylose (27%) and amylopectin (75%). For various agro-industrial reasons, some countries are trying to increase some form of starch. Given the importance of corn in the global diet, improving the quantity and quality of grain protein is happening everywhere. Attempts are now being made to produce varieties of corn with high protein content and rich in certain generally deficient amino acids such as lysine and tryptophan [5].

Maize grain yield depends on the genetic potential of the genotype used, soil characteristics, field management practices and agro-climatic factors. Yield potential is largely determined by a specific combination of several factors, such as solar radiation, soil type, temperature, plant density, genetic potential of a given genotype, biotic and abiotic constraints [6]. All these different factors are potential causes of chronic food shortages encountered in Africa and, in particular, in the Democratic Republic of Congo (DRC) by the fact that they affect most plants of agronomic and economic interest by decreasing accordingly their values. The produces crop yields could which accentuated by the gradual loss of soil fertility, which is added to it, thus worsening the low purchasing power of farmers [7]. All these problems require an adequate and lasting solution to obtain the expected return.

Today, the improvement of the main cultivated species sets themselves various objectives including that of creating new varieties which must, on the one hand, have a good level of production, be adapted to climatic conditions, and resist multiple diseases and parasites. On the other hand, they must also satisfy the tastes of consumers and the needs of the agro-industry [5]. Plant breeding can be defined as the selection of certain traits of plants to better meet human needs [8]. Several methods are used to improve plants depending on the goal that the improver has set for it. Site-directed mutagenesis is one of the many techniques known in agronomy [9], [10].

The FAO / IAEA database indicates that irradiation, especially gamma irradiation, is most often used to induce mutations in crop plants. The reason is simple that gamma irradiation offers better mutation efficiency than any other ionizing radiation [11].

With a view to making improved varieties of local maize available to farmers in the near future, which would increase its yield and combat the various disastrous soil conditions in the town of Kenge, gamma radiation has been used to irradiate locally produced maize in order to analyze the effects of irradiation for possible improvement of this cereal [5].

This study will demonstrate the gamma radiation importance in the crop plants improvement, in this case corn in our region and thus promote the agriculture promotion for the development by researchers of techniques of crop plants 'improvement and other plants of agronomic utility by gamma radiation especially, since food security is an

emergency which requires substantial resources and appropriate techniques.

II. MATERIAL AND METHODS

A. Study Environment

The study was carried out on a site located in the EPOM district near the REGIDESO pumping station in the Municipality of MAVULA in the city of KENGE from February 20 to June 29, 2018. The geographical coordinates of the experimental site are presented as follows: 4° 47' 3.64" South latitude and 17° 03' 31.7" East longitude and 390 m altitude (Coordinates taken using GPS Elite).

B. Irradiation of Corn Seeds

The Gamma Ray Irradiator CONSERVATOME Lisa I with Cesium-137 (¹³⁷Cs) source from Biochemistry and Food Technology Department at CGEA/CREN-K was used for corn seeds irradiation. The irradiator consists of several bars containing the ¹³⁷Cs nuclei which emit a gamma ray of 661.6 keV in a parallelepiped chamber 43 cm long, 24 cm wide and 30 cm high.

The dose rates of seeds exposed to level V closer to the source of ¹³⁷Cs at the irradiation time were calculated using the following exponential decay relationship:

$$Do = Dt \cdot e^{\frac{-\lambda t}{T}}$$

Where:

Do: theoretical dose emitted on the calculation day;

Dt: calibration dose or the dose emitted on the day of installation May 1976;

e: Natural logarithm (2.7182818);

λ : Mathematical value of lambda (0.693);

t: time from installation (May 1976) to the day of the dose exposure (January 2018);

T: half-life of ¹³⁷Cs, ie 30.15 years.

After preliminary study carried out in the Life Sciences Division laboratory, seeds were irradiated at doses from 100 to 600 grays in order to determine the radioactivity sensitivity on corn kernels by the germinating, and then the study proper on the irradiation of corn seeds was carried out. The procedure consisted of irradiating the grains at doses of 100, 200 and 300 Grays (Gy) through the Petri dishes using the CONSERVATOME Lisa I irradiator.

C. Experimental Apparatus

The trials were carried out in the open field in season B following the DRC agricultural calendar under uncontrolled and non-reproducible conditions, close to practice. The experimental device used in this study is the device in completely randomized blocks taking into account the "Latin square" [12]. The field was 14 m long and 12.6 m wide, giving an area of 176.40 m². The plots, each measuring 2.5×2.5 m was spaced 0.5 m from each other giving a total of 16 plots for four treatments including the control (non-irradiated seeds T0: 0 Gy), the seeds irradiated at 100 Gy (T1: 100 Gy), seeds irradiated at 200 Gy (T2: 200 Gy) and seeds irradiated at 300 Gy (T3: 300 Gy).

D. Sowing

After the demarcation of the land and the experimental plots, the plowing and maintenance then the staking and the distribution of the blocks which followed, two corn grains were sown in each pocket at spacing of 0.8×0.5 m under a depth of 5 cm according to the standards of the cultivation of corn. To sow the area, 480 seeds were sown including 120 seeds for each of the irradiation doses and 120 seeds for the control.

To carry out this study and achieve the expected results, some cultural precautions were taken such as weeding which took place regularly whenever the need arose, hilling at the same time as weeding, mulching, and watering which was done twice a week often at sunrise or sunset.

E. Determination of Radiosensitivity

In order to minimize damage to the DNA molecule by mutagens and reduce unwanted mutations [13], [14], the LD50 was determined. In this study, the radiosensitivity of the local variety of *Zea mays* to gamma radiation (Cs^{137}) was previously determined by the regression equation obtained in Fig. 1.

Fig. 1. Radio-sensitivity of corn seeds (*Zea mays*) to gamma rays (Cs^{137}).

F. Data Analysis

Data were subjected to analysis of variance (ANOVA) with STATISTICA with general linear software and LSD (Least Significant Difference) test.

III. RESULTS AND DISCUSSION

The results obtained during this experiment are shown in the tables shown below.

A. Results

1) Choice of doses for a local maize improvement program

For a breeding program for a given plant species, the determination of LD30 and LD50 is recommended [14], [15]. For the case of the local variety of maize, the values of LD50 and LD30 obtained by the regression equation ($y = -0.135x + 72.86$) in Fig. 1 are 169.33 Gy and 317.48 Gy, respectively.

2) Growth parameters

The germination rates of the kernels, the diameter at the crown of the plants, the size of the plants and the amount of leaves / plant of maize (*Zea mays* L.) are shown in Table I.

Irradiation with gamma radiation (Cs^{137}) negatively affects the various growth parameters compared to the control except for the diameter at the neck (Fig. 1).

However, the germination is seen to increase by 3.08% compared to that of the control at 100 Gy and the plant size by 8.16% at 100 Gy and 1.21% at 200 Gy. These two parameters, average rate of germination and average height of the plants were reduced by 70.77% and 66.86% respectively compared to the control at 300 Gy.

It appears from Table I that the growth parameters of maize, including plant size and the number of leaves/plants, were not affected by the irradiation doses because F-cal for these two parameters was lower than the F-Tab.

TABLE I. Maize (*Zea mays* L.) Growth of in the Field

Treatments (Gy)	Germination (%)	Diameter at crown (cm)	Average height of plants (cm)	No. of leaves / plant
0	65±6 a	2,45±0,86 c	204,15±4,20 a	14±1 a
100	67±5 a	3,51±0,37 ab	220,80±21,33 a	14±0 a
200	58±4 b	3,94±0,13 a	206,62±7,12 a	14±1 a
300	19±1 c	3,29±1,31 ab	67,66±78,13 a	12±3 a
CV	4.96	14.32	95.37	2.18
F-cal	148.9546	3.5337	0.0285	1.125
F-Tab.	3.48	3.48	3.48	3.48
ppds	5.8656	1.0671	—	—

Legend: CV: coefficient of variation, ppds: smallest significant difference, F-cal: calculated values of F for $p = 0.05$, F-Tab: Tabular values of F for $p = 0.05$.

The other two parameters, germination rate and crown diameter, were affected by radiation doses because F-cal was greater than F-Tab. For the germination rate, the dose of 100 Gy with $67 \pm 5\%$ showed the higher germination rate compared to the other treatments and the control. Statistically, the germination rate of seeds irradiated at 100 Gy does not show a significant difference at the confidence level of 5% with the germination rate of non-irradiated seeds (0 Gy) but presents a significant difference with those of 200 Gy and 300 Gy. The dose of 300 Gy with $19 \pm 1\%$ negatively affects the germination of maize.

3) Relationship between irradiated and non-irradiated field parameters

Fig. 2. Ratio (%) between growth parameters from irradiated corn kernels and control kernels as a function of the irradiation doses.

For the mean neck diameter of the plants, the irradiated seeds showed high values of the neck diameter compared to the control (2.45 ± 0.86) and this is the dose of 200 Gy with 3.94 ± 0.13 cm which presented higher value than other doses of irradiation. Statistically, this value does not differ with those of the other doses, respectively 3.51 ± 0.37 cm and 3.29 ± 1.31 cm, but they all differ from that of the control at the 5% confidence level.

4) Maize (*Zea mays*) production in the field

The production of maize (*Zea mays*) in the field is shown in Table II according to the various parameters measured: length of the ears, diameter of the ears, number of kernels/cob, weight of 100 kernels and the yield per plot. Because the easiest and more reliable methods of yield estimation are based on yield parameters collected from the field [16].

Only the diameter of the ears was not modified by the irradiation doses, but the other parameters such as the length of the ears, the number of grains/ear, the weight of 100 grains and the yield per plot were affected by the different irradiation doses and their values show significant differences at threshold of 5% from each other (Table II). However, the 100 Gy dose showed high values for all parameters: 15.91 ± 1.10 cm for the average length of ears, 81.25 ± 6.29 mm for the average diameter of the ears, 1505 ± 154 kernels / ear, 327.25 ± 18.73 g/100 kernels and 530 ± 29.87 g / plot.

5) Ratio (%) of field parameters between controls plants (0 Gy) and irradiated plants

Fig. 2 illustrates the different ratios (%) obtained from the irradiated plants and from the control plants in the field.

Fig. 2. Ratio (%) between reproduction parameters and yields from irradiated corn kernels and those of the control as a function of irradiation doses.

The dose of 100 Gy causes an increase in the length of the ears, the diameter of the ears, the number of grains/ear, the weight of 100 grains and the yield / plot compared to the control, respectively by 57.06%; 3.17%; 32.60% and 35.23% (Fig. 2). These ratios are reduced with increasing doses of gamma irradiation (Cs¹³⁷) to 200 and 300 Gy. The yield was more affected at 300 Gy to values decreasing around 60% compared to the control.

B. Discussion

The present study sought to determine the effect of gamma radiation on seedling germination and growth as well as on the kernel yield of a local variety of maize (*Zea mays*). The seeds were planted after irradiation without application of fertilizer.

The results obtained show that, for local maize, most of the parameters measured in this study were negatively affected by gamma radiation (Cs¹³⁷) except for the diameter at the neck for all the irradiation doses used. The dose of 100 Gy, for its part, gave higher values for all the parameters measured on irradiated plants compared to the non-irradiated plants (control). These results corroborate with so many others obtained on the effects of mutagens applied on crop plants [17]-[19] which affirm that the effects of doses of the irradiation varies according to they have whether be positive, increasing an existing trait depending on the dose of gamma ray applied, or negative, decreasing or eliminating a trait which existed for such other dose.

As regards the germination rate ($67 \pm 5\%$) for the 100 Gy dose, it does not differ significantly from that of the control ($65 \pm 6\%$) at the 5% confidence level. Higher doses provided low germination rates compared to the control. However, the germination rates obtained in this study were found to be lower than those obtained by [20] who obtained higher corn kernel germination rates where even the dose of 500 Gy gave a rate of 68.69%. This could be explained by the genetic difference in the plant material used. However, the present results corroborate those of these authors who reported that the dose of 100 Gy presented a high germination rate compared to all irradiated as in this study.

Unlike the irradiated corn kernel yield obtained by [6] which had been increased to levels above the unirradiated yield with doses up to about 250 Gy and the optimum yield occurring at 150 Gy, the superior yield obtained in this work is at the dose of 100 Gy with 327.25 ± 18.73 g per 100 seeds. This could be due to factors of changes in sensitivity to gamma rays, the most important for seed irradiation being the oxygen and water content [2].

Regarding growth parameters such as ear length, ear diameter, number of kernels / ear and seed weight (100 kernel weight), they were also positively affected by gamma radiation (CS¹³⁷) with 100 Gy or negatively with 200 and 300 Gy compared to the absence of radiation (0 Gy). A good number of authors admit that the observed characters depend on genetic factors but also on environmental factors because the phenotype is only the sum of genetic and environmental factors [21], [22].

TABLE II: PARAMETERS PRODUCTION AND YIELD PER CORN PLANT

Treatments (Gy)	Ear plant length (cm)	Ear diameter (mm)	Number of kernels/ear	Weight of 100 grains (gr)	Yield/plot (g)
0	10,13±1,05 c	78,75±2,50 a	1135±198 ab	242,00±39,89 b	392±64,89 b
100	15,91±1,10 a	81,25±6,29 a	1505±154 a	327,25±18,73 a	530±29,87 a
200	12,08±0,88 b	80±0,00 a	1211±284 ab	205,25±29,99 b	332,5±48,24 b
300	10,78±1,29 bc	60±40,82 a	713±508 c	90,50±72,54 c	147±117,71 c
CV	6.622	19.63	19.73	14.25	20.25
F-cal	20.4756	0.9327	4.2132	20.31	20.2493
F-Tab.	3.48	3.48	3.48	3.48	3.48
ppds	1.8294	=	508.697	69.63	112.81

Legend: CV: coefficient of variation, ppds: smallest significant difference, F-cal: calculated values of F for p = 0.05, F-Tab: Tabular values of F for p = 0.05.

IV. CONCLUSION

The objective of this study was to analyze the effects of gamma radiation (Cs^{137}) on field growth of a local variety of maize according to radiation doses (0, 100, 200 and 300 Gy). Our results show that the dose of 100 Gy provided good growth in the field taking into account the parameters studied compared to the control and a good yield compared to the irradiation doses of 200 and 300 Gy. The value of LD50 (169.33 Gy) obtained could make it possible to establish a program for the improvement of this local variety of maize and that dose above 200 Gy could already be discarded beforehand.

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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