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NOTE

The effect of gamma irradiation on the germination and growth of certain Nigerian agricultural crops

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Abstract

Gamma irradiation has been found to be very useful both for sterilisation in medicine and the preservation of food and cereals in nutrition and agriculture. This investigation was carried out to determine the effect of gamma irradiation on the subsequent germination and growth of irradiated seeds. Thirty seeds each of maize, okra and groundnut were irradiated to varying doses of 150, 300, 500, 700, 900, 1000 Gy using the ^{60}Co gamma cell irradiator facility at the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife. These, as well as the controls (unirradiated seeds), were planted on the same day in an already prepared area of farmland during the rainy season to ensure a constant moisture flow. The times of germination and subsequent growth were monitored. Results show that maize, okra and groundnut seeds needed for planting can be safely stored using gamma irradiation. However, the study reveals that the number of germinated seeds and the growth rate for the crops decrease with increase in the radiation dose the seeds were exposed to. Third-degree polynomial equations were derived which describe the percentage germination of the crops at various levels of exposure. A chart of percentage germination of seeds versus exposure dose is also presented as a quick guide to farmers, policy makers and agricultural institutions.

1. Introduction

Irradiation is a process of exposing substances to radiant energy or ionising radiation. In the context of this research, it can be defined as the process of exposing crops to carefully controlled amounts of energy (Opadokun 1996, IFST 1999). The process is useful in solving various agricultural problems: reduction of post-harvest losses through suppressing sprouting and contamination, eradication or control of insect pests, reduction of food-borne diseases and

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in extension of shelf life, and breeding of high-performance well adapted and disease resistant agricultural crop varieties (Andress *et al* 1994, Emovon 1996).

Research on food irradiation dates back to the turn of the twentieth century with the first United States of America and British patents being issued in 1905. It allowed the use of ionising radiation to kill bacteria in food (ICGFI 1999). The United States have since amended their drug regulations to allow the irradiation of certain food products to control food-borne pathogens (USEPA 2002).

In Nigeria, this nuclear technique has been tested and analysed at an experimental level on cereals, legumes, roots and tubers as well as fish and livestock. It has been identified as a process that can potentially play a major role in the pursuit of healthy and abundant food supplies for all (Umar 1994).

Gamma radiation of 30–1000 Gy has been applied to achieve a delay in the ripening of some fruits and vegetables (WHO 1988). A reduction in the amount of visible and total mould present in bread during a storage period of up to 20 weeks was reportedly achieved by applying a gamma radiation dose of 150 Gy to the flour (Adejumo 1998).

Bansa and Appiah (2003) have also reported the successful use of gamma radiation dose of 120 Gy to effectively inhibit sprouting in yams for six months under tropical ambient conditions. Furthermore, higher gamma radiation doses of 2–4 kGy have been used to successfully reduce the infection rate in sugar beet seeds (Rizk and Moussa 2003) while a dose of approximately 500 Gy has been employed to disinfect and also reduce microbial populations in cocoa beans (Adesuyi 1996).

For Nigeria to sustain her food security policy, it is imperative that the issue of food preservation is given priority. Consequently, the Sheda Science and Technology Complex, SHESTCO at Abuja is equipped with a multipurpose gamma irradiation plant which has a number of associated laboratories (Adesanmi 2002, Coker 2002). The immense benefits derivable from this technology should therefore be made available to individuals, food companies and agricultural institutions through the varied sources provided by this institution.

This work, the first phase of a series of studies aimed at finding out the effect of irradiation on some Nigeria crops, is intended to investigate how the preservation of agricultural crops using gamma irradiation affects the germination and subsequent growth of these crops.

2. Materials and methods

Three common Nigerian crops—maize, okra and groundnut—were used in this study. Large quantities of the samples were purchased from the open market in Nigeria. Each seed was subjected to a careful observation in order to select seeds still having their micropyle in place. These seeds were then packed in groups of 30 seeds per crop. These seeds were later subdivided and labelled as S_0 to S_6 where S_0 is the control seed group and S_1 to S_6 are seeds to be irradiated with different doses of γ-rays (150, 300, 500, 700, 900 and 1000 Gy respectively).

Irradiation was undertaken at the Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Nigeria, using a Gammacell 220 irradiator facility[2]. This ^{60}Cobalt irradiator facility is capable of delivering 10 Gy of γ-rays for every 28.97 s exposure.

Three groups, each of 10 seeds of each of the irradiated maize, okra and groundnut seeds as well as their controls were planted on the same day to enable the seeds to grow under the same physical conditions on an already prepared and fenced area of farmland measuring 16 m $\times$ 20 m procured for the purpose. The fencing was done to prevent all forms of intrusion both from

[2] Atomic Energy of Canada Limited (AECL).

Control	**150Gy**	**300Gy**	**500Gy**	**700Gy**	**900Gy**	**1000Gy**	
S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}	
S_{20}	S_{21}	S_{22}	S_{23}	S_{24}	S_{25}	S_{26}	Maize
S_{30}	S_{31}	S_{32}	S_{33}	S_{34}	S_{35}	S_{36}	
S_{40}	S_{41}	S_{42}	S_{43}	S_{44}	S_{45}	S_{46}	
S_{50}	S_{51}	S_{52}	S_{53}	S_{54}	S_{55}	S_{56}	Okra
S_{60}	S_{61}	S_{62}	S_{63}	S_{64}	S_{65}	S_{66}	
S_{70}	S_{71}	S_{72}	S_{73}	S_{74}	S_{75}	S_{76}	
S_{80}	S_{81}	S_{82}	S_{83}	S_{84}	S_{85}	S_{86}	Groundnut
S_{90}	S_{91}	S_{92}	S_{93}	S_{94}	S_{95}	S_{96}	

Figure 1. Illustration of the planting arrangement.

Table 1. Percentage of seeds germinated at the end of germination.

	% of seeds germinated		
Samples	Maize	Okra	G/nut
Control	97	100	100
150 Gy	93	97	90
300 Gy	90	83	87
500 Gy	80	80	83
700 Gy	73	67	77
900 Gy	67	63	70
1000 Gy	57	47	60

neighbours and from animals. The planting arrangement took the form of a rectangular array of a 9×7 matrix for the three crops as shown in figure 1. Markers and sticks were used to ensure identification of the doses of the planted seeds.

The farming method used in this study is monocropping. The planting was carried out during the rainy season to guarantee uniform soil moisture movement.

The planted seeds were observed daily until germination commenced. The dates of commencement and termination of germination as well as the number of seeds that germinated for each day were noted for each of the samples. Plant growth in terms of height was measured weekly using a metre rule. Each measurement was carried out twice and the mean height was recorded. Data from the height measurements for the crops over a period of eight weeks were statistically analysed.

3. Results and discussion

The planting arrangement for each of the irradiated crops is shown in figure 1 while the percentages of germinated seeds at the end of germination are shown in table 1. From this table, it is clear that the percentage of germination decreases significantly as the exposure dose

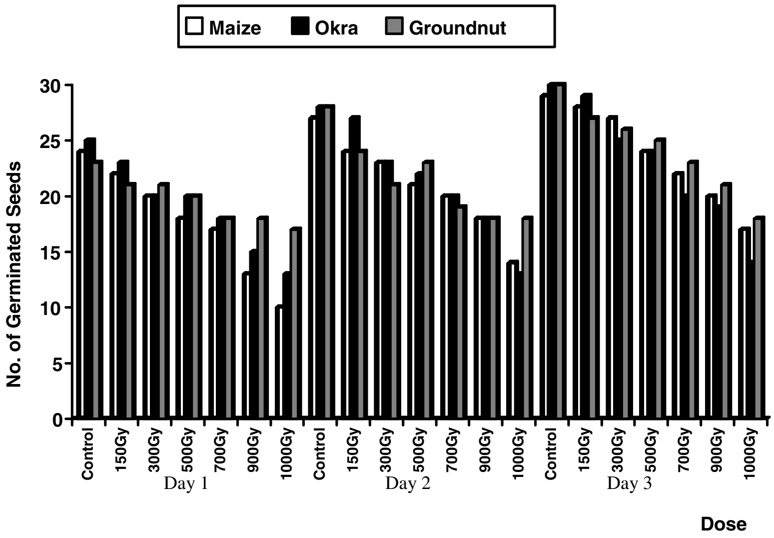

Figure 2. Differences in germination between the control and the irradiated seeds.

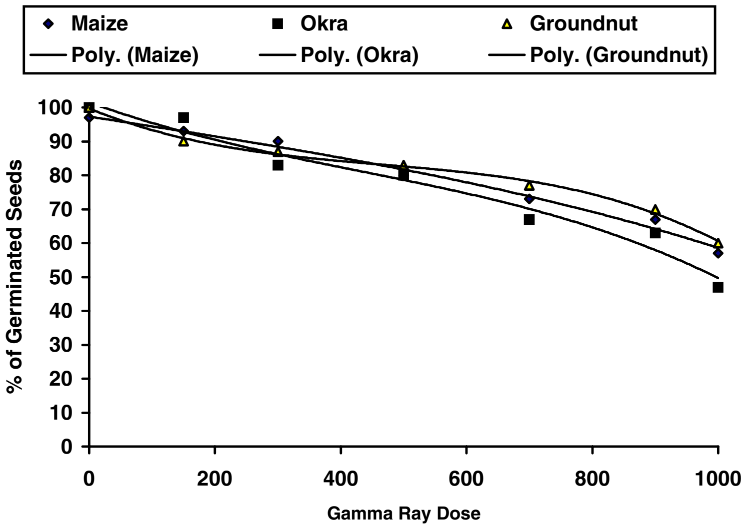

Figure 3. A plot of the relationship between germination and gamma irradiation dose for the experimental data.

increases. It is also observed that a dose of 150 Gy had little effect on the germination rate of maize and okra, while in groundnut the loss of germination amounts to about ten per cent.

The difference in germination between the control and the irradiated seeds is presented in figure 2. From this figure, it is obvious that the number of germinated seeds reduces generally with increasing gamma radiation dose.

The actual relationship between gamma irradiation dose and percentage seed germination for each crop is illustrated in figure 3. Third-degree polynomial equations were derived which describe the percentage germination of the crops at various levels of exposure. The equations

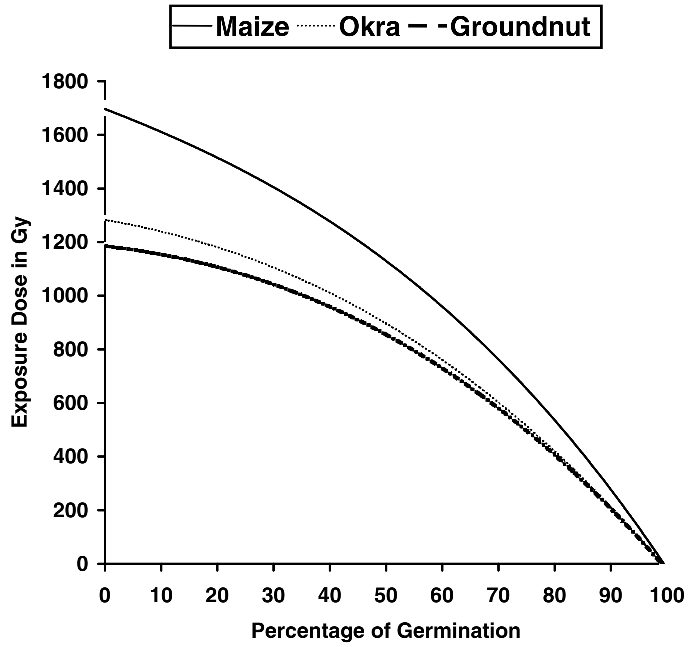

Figure 4. Gamma irradiation dose versus percentage germination using the polynomial equations.

are

$$\text{Maize:} \quad \%\text{GS} = -1 \times 10^{-8} D^3 + 5 \times 10^{-7} D^2 - 0.0289D + 97 \quad (1)$$

$$\text{Okra:} \quad \%\text{GS} = -6 \times 10^{-8} D^3 + 7 \times 10^{-5} D^2 - 0.0674D + 100 \quad (2)$$

$$\text{Groundnut:} \quad \%\text{GS} = -9 \times 10^{-8} D^3 + 1 \times 10^{-4} D^2 - 0.0756D + 100 \quad (3)$$

where D is the gamma irradiation dose in Gy and GS is the percentage of germinated seeds. The choice of the third-degree polynomial is as a result of the functional relationship between it and the plotted curves as shown in figure 3 (Anomohanran 2004). From equations (1)–(3), one can estimate the percentage of germination expected once the crops are exposed to a given dose of γ-ray irradiation. Figure 4 is a plot of the theoretically determined relationship between percentage germination expected for a given exposure dose using equations (1)–(3). Thus, to achieve a germination of 90% in maize, the gamma radiation dose should be about 240 Gy (figure 4). On the other hand, to achieve the same percentage germination in okra, a gamma radiation dose of about 170 Gy is required, while for groundnut the gamma irradiation dose should be about 160 Gy.

In figures 5–7, the plots of plant height measured over time for the three are presented. From these figures, one observes that growth rate decreases with increase in the dose of gamma radiation for all three. The seeds which are irradiated with low gamma radiation grow higher than those irradiated with a high dose. This means that the higher the exposure dose of gamma irradiation to the seeds, the poorer the growth performance of the crop. While a dose of 150 Gy appears to have little effect on the growth rate of maize as shown in figure 5, it appears to stimulate growth in okra (figure 6). Doses up to 500 Gy have little effect on the growth rate for groundnut.

The heights attained by the three crops for the eight-week period of germination for each different dose were correlated by regression analysis (Davis 1973). The results obtained show

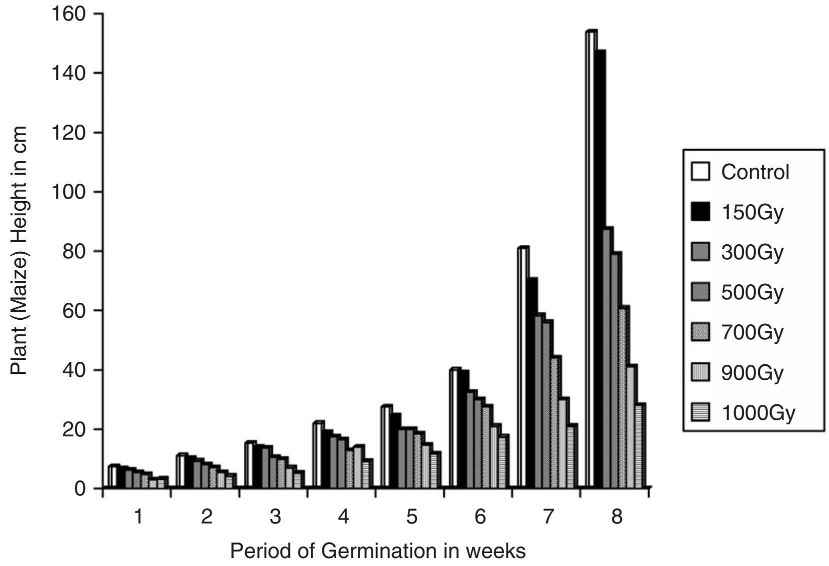

Figure 5. Plant height versus time after germination for the control and irradiated maize seeds.

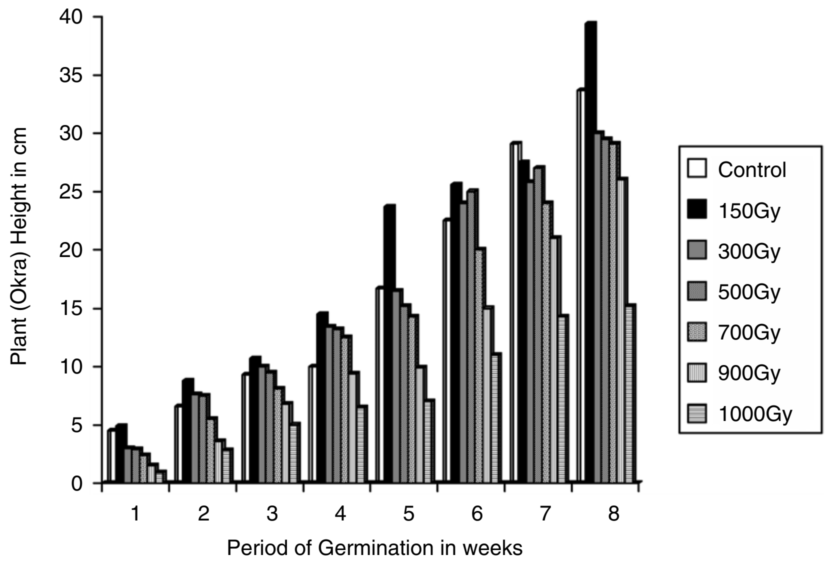

Figure 6. Plant height versus time after germination for the control and irradiated okra seeds.

that the differences in heights for the different doses were significant at the 0.01 level of correlation. With this result, farmers and storage houses should be aware that for better yields to be obtained, seeds/crops meant for planting should be stored using minimal γ-ray radiation.

4. Conclusion

This study has provided information on the use of gamma irradiation as a storage tool for maize, okra and groundnut. It also provided information on the germination and growth responses

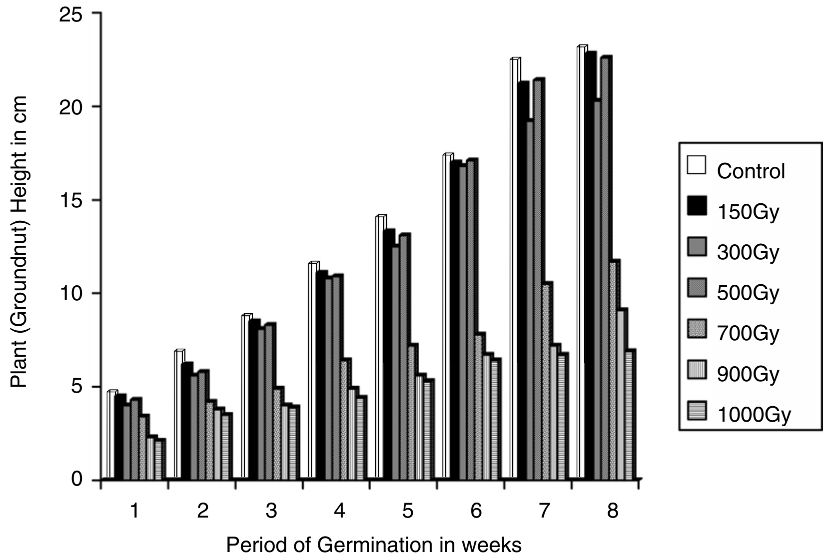

Figure 7. Plant height versus time after germination for the control and irradiated groundnut seeds.

of the seeds irradiated with gamma radiation. There is enough evidence from the various graphs in this study to show that the exposure of the crops to gamma irradiation affects the number of germinated seeds and the growth rate. It is clear from the study that crops which are needed for replanting should only be exposed to a minimum amount of gamma radiation—using figure 3 as an aid. From the foregoing, it is recommended that in the administration of gamma irradiation as a means of storing the three crops in this study, the ALARA (as low as reasonably achievable) principle should be adopted (Anomohanran *et al* 2002). This will ensure that while using gamma rays to store the crops, their germination potentials are not jeopardised or compromised in any way.

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