

Effect of X-Ray Exposure and Sodium Azide (NaN_3) Treatments on Germination Growth and Yield of Maize (*Zea Mays* L.) in Mubi Adamawa State Nigeria

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Abstracts - A Research was carried out at the Faculty of Agriculture Department of Crop Science Teaching and Research Farm, and Botany Laboratory of Adamawa State University, Mubi, during the 2024 cropping season to determine the effect of X-ray bombardment and sodium azide on the germination, growth and yield of maize (SAMMAZ 51) an open pollinated variety. The treatments consisted of the following; T1=SA₁0.01% T2 = SA₂0.02% T3= SA₃0.03% T4= X-ray 5sec, T5= X-ray 10 sec, T6=X-ray 15 sec and T7= control. The Experiment was laid out in a Randomized Complete Block Design (RCBD) in three replicates. Data were collected on days to first germination, germination percentage, number of leaves, plants height, days to 50% tasseling and silking, number of cobs per plot, number of rows per cob, cob length (cm), seed yield per plot(g), 1000 seed weight (g) and seed yield (kg ha⁻¹). The data collected was subjected to Analysis of Variance using Statistical Package for Scientist and Engineers (SPSE), significant means were separated using Duncan Multiple Range Test (DMRT) at P≤0.05. The results showed that bombarding maize seeds with X-ray for 10 seconds prior to planting performed better in most of growth and yield characters observed in this study the characters were, days to first germination with 3 days, germination percentage 72.91 %, number of leaves and plant height at 2 and 4 weeks after sowing as 5.53 and 10.07, 18.13cm and 31.27 cm respectively number of cobs per plot 5, number of rows per cob 12.73, seed yield per plot 325.08 (g), 1000 seed weight 217.08 (g), and seed yield (kg ha⁻¹) 543.78. This study therefore revealed that bombarding maize seed (SAMMAZ 51) with X-ray for 10 seconds prior to planting can enhance germination, growth and yield of maize. Hence X-ray can serve as an important mutagenic agent for creating variability in maize.

Keywords: X-ray, Sodium azide, Growth, Yield, Maize.

I. INTRODUCTION

Maize (*Zea mays* L.) is a major cereal crop, which belongs to the family *poaceae*, it is a major staple food in developing countries, maize is one of the most important cereals in the world after wheat and rice. In Sub-Saharan Africa, over 80% of the people depends on it as a source of food, income and livelihood (Pardey *et al.*, 2016).

The global maize area for cultivation is about 197 M ha, including substantive areas in sub-Saharan Africa, Asia and Latin America (FAOStat, 2021). Maize is an important human food in a number of countries, especially in sub-Saharan Africa, Latin America, and a few countries in Asia, where it is consumed as human food contributing over 20% of food calories (Shiferaw *et al.*, 2011). In the developed economies it is primarily used as a livestock feed. Maize therefore plays a great role in food security (Grote *et al.*, 2021).

United States of America (USA) was the largest producer of maize in the world with an estimated production of about 389.6 million metric tons (MMT) contributing 32% of the world production, followed by China with about 288.8 MMT contributing about 23% of the world production. In Africa the only country that makes the top ten producers of maize is South Africa with an average production rate of about 15.5 MMT contributing about 1% of the world production (FAOStat, 2021).

Nigeria produced an estimated 12.7 million metric tons (MMT) of maize, with an average yield of 2.2 tons per hectare, Despite the increase in production realized over the years, the yield is still very low when compared with some developed countries of the world and other African countries (FAOStat, 2021),

Research efforts by breeders and agronomists have led to the production of many technologies including the breeding for high yielding varieties that are tolerant to drought,

diseases, low nitrogen consumption, and Striga infestation (Kamara *et al.*, 2014).

Numerous research organizations are working together at the national and international levels to solve the question on “How to feed more than nine billion people in 2050?” The United Nations Food and Agriculture Organization (FAO) 2015 emphasized the food security issues and estimated that agricultural production must increase by 70% to meet the food demands of an expected 9.1 billion people by 2050.

Drastic climate change and increases in extreme weather conditions such as floods, drought, heat, and salinity, pose significant risks to agriculture. Coordinated action across primary research and funding organizations is required to maximize agricultural productivity/ genetic gain. The consistent use of conventional breeding approaches has reduced genetic variability, which is the main prerequisite for crop improvement programs (Holme *et al.*, 2019). Therefore, new breeding techniques such as mutagenesis are required to accomplish the goals of increased genetic variability. Besides genetic variability, induced mutagenesis offers an opportunity to improve a single character without altering the entire genetic constitution (Shu *et al.*, 2012).

Mutation breeding is an effective tool used by plant breeders for genetic improvement of autogamous crops with narrow genetic base and developmental phenomena (Eze and Dambo, 2015). It alters one or two major desired agronomic traits which limit their productivity or enhance their quality (Adamu and Aliyu 2007, Roychowdhury and Tah 2011). Mutagenesis has a potential of inducing Polyploidy in crop plants which is an important feature found in eukaryotes, it played key role in plant speciation, diversification, evolution and breeding which leads to variation in plant phenotype (Nura *et al.*, 2023).

Induced mutation using physical and chemical mutagens is a method used to create genetic variation resulting in new varieties with better characteristics as reported by (Wongpiyasatid *et al.* 2000 and Arulbalachandran *et al.* 2009). Sodium azide (NaN_3), is a chemical mutagen which is considered as one of the most powerful mutagens in plants, its application on plant is easy and inexpensive and creates mutation to improve their traits. The efficiency of mutant production depends on many conditions such as pH, soaking into water, temperature, concentration of azide and treatment duration. It creates point mutation and damages the chromosomes and thus produces tolerance in the plants for numerous adverse conditions (Al-Qurainy and Khan, 2009). Sodium azide was used in many studies to induce mutation as found by (El-Nashar, 2006) on *Amaranthus caudatus*, (Al-Gawwad and Makka 2009) on *Mirabilis jalapa* and Mostafa

(2011) on *Helianthus annuum*. Mutation breeding is relatively a quicker method for improvements of crops. It has been observed that induced mutations can increase yield as well as other quantitative traits in plants. Since the discovery of radiation and chemical mutagens, a large amount of work has been done on study of radio sensitivity of crop plants with ionizing radiations and chemical mutagens (Caldecott, 1955).

Unfortunately, the use of X-ray and sodium azide as a mutagenic agents for enhance productivity in maize has not received much attention by breeders in Nigeria. This may be partially due to hazardous nature of this substances or lack of availability of this mutagenic agent in the country. In some developed countries today mutation breeding is growing steadily with many varieties of crops with novel characters such as Rice, maize, sugarcane released for cultivation across the countries such as Russia, India, China USA etc.

Mutation induction has been successfully used to induce genetic variability in many crops, allowing the isolation of mutants with desirable characters of economic importance such as yield and earliness (Wongyai *et al.*, 2001), modified plant architecture, closed capsules, disease resistance (Çagirgan, 2001), seed retention, larger seed size, desirable seed color and high oil content (Hoballah, 2001). Crop improvement therefore depends on the genetic variability and the extent to which the traits are heritable.

Ionizing radiation has paved its way in revolutionizing modern day researches in the field of agriculture and food technology. X-ray as stated by Marcu *et.al* (2012) has been proved to be economical and efficient as compared to other ionizing rays and also because of its penetrating power, it has wider scope of application in enhancement of different plant species (Moussa, 2006).

The Plant Mutant Variety Database of the Joint FAO/IAEA Centre of Nuclear Applications in Food and Agriculture currently holds the records of over 3300 released mutant varieties of various crop plants of which more than 80% involve the use of ionizing radiation such as X-Ray and gamma rays (FAO/IAEA 2021).

That is why this research was carried out to determine the effect of X-rays and sodium azide on the germination growth and yield of maize with the objective of selecting the best mutagenic level, that can help enhance the germination growth and yield of maize, in order to tackle the problem of food security in Nigeria.

II. MATERIALS AND METHODS

Experimental site

The research was carried out in Botany Laboratory Adamawa State University Mubi and the Research Farm of Department of Crop Science, Adamawa State University, Mubi. The research farm location falls within the North Eastern region of Nigeria, between Latitude 10016' 06" N and Longitude 13016' 01" E; and has an elevation of 582 m above sea level.

Seed collection

Maize variety that was used for this research was SAMMAZ 51, is an open pollinated variety which was obtained from International Institute for Tropical Agriculture (IITA) Ibadan.

Treatments Formulation

The maize seeds were pre-soaked in distilled water in a beakers and left for about 6 hours at room temperature, the seeds were constantly agitated to facilitate aeration. The seeds were then removed from the water and the excess moisture removed by pressing on a filter papers. They were then treated with varying concentrations of sodium azide as follows: SA₁= 0.01%, SA₂=0.02 %, SA₃= 0.03 % using the procedure described by Klu *et al.* (2000). After each treatment, the seeds were washed to remove excess chemicals under running tap water for about 20minutes. The seeds were then spread out on blotting papers to surface dry in order to prevent the occurrence of artefacts. Other seeds were then exposed to X-rays at 90 KeV for 5, 10 and 15 sec as follows X-ray 5 sec, X-ray 10 sec and X-ray 15 sec.

Land preparation, planting and Experimental Design

The land was cleared from debris, plough using tractor and harrowed. Two viable seeds were planted per hole at a spacing of 75cm x 50cm inter and intra row spacing respectively using manual planter. The experiment was laid out in a Randomized Compete Block Design (RCBD) in three (3) replicates. All standard agronomic practices aim at enhancing the productivity of maize was strictly followed.

Data collection

Germination percentage: The treated seeds were taken to the laboratory placed inside a plastic container placed on a moist cotton wool as soon as the radical began to emerge, it indicated that the seeds were viable and the germination percentage was calculated as follows:

$$\text{Germination \% (GER \%)} = \frac{\text{Total Number of seed germinated}}{\text{Number of seed sown}} \times 100\%$$

Days to first germination: The number of days from sowing to appearance of the first radical was counted and recorded.

Number of leaves: The number of leaves from each treatment was counted and recorded at 2 weeks interval.

Plant height: The plant height was measured from the base of the plant to the tip of plant in cm using meter rule.

Days to 50% tasseling: The number of days from sowing the time at which 50% of the maize in each treatment has tasseled was recorded.

Days to 50% silking: The number of days from sowing the time at which 50% of the maize has silked was recorded.

Number of Cob per plot: The number of cob harvested from each treatments was counted and recorded.

Number of rows per Cob: The number of rows from each cob in each treatment was counted and recorded.

1000 kernel weight: One thousand seed was counted from each treatments and weigh using electronic weighing balance (g).

Seed yield per plot: The yield obtained from each treatment was weigh in the laboratory using electronic weighing balance.

Seed yield in kg/ha: The seed yield in Kg/ha was the calculated from the seed yield perplot using the formula below.

$$\text{Seeds yield (kg/ha)} = \frac{\text{Seeds yield per plot in (kg)}}{\text{Area of the sub plot (m}^2\text{)}} \times 10,000\text{m}^2$$

Data Analysis

The Date collected was subjected to two way Analysis of Variance (ANOVA) using Statistical Package for Scientist and Engineers (SPSE). Significant mean was being separated using Duncan Multiple Range Test (DMRT) at $P \leq 0.05$.

III. RESULTS

Effect of X-ray Exposure and Sodium azide (SA) on Days to First Germination and Germination percentage

The Analysis of variance (ANOVA) showed significant difference at $P < 0.05$ for Days to first Germination and

germination percentage it Table 1, it took the maize seeds treated with X-ray for 10 sec 3 days to germinate compared with the other treatments, which took longer days to commenced germination. The trend was also same for germination percentage; seed treated with X-ray for 10s recorded the highest germination percentage of 73% while those treated with sodium azide SA0.02% recorded the lowest germination percentage of 10%. (Table 1).

Effect of X-ray Exposure and Sodium azide (SA) on Number of Leaves

The Analysis of Variance (ANOVA) showed significant difference at $P < 0.05$, for number of leaves with seeds treated with X-ray for 10sec recorded the highest number of leaves of 5.53, 10.07 at 2 and 4 weeks after sowing respectively while those treated with SA0.02% recorded the lowest number of leaves of 3.27 and 5.00 at 2 and 4 weeks after sowing respectively (Table 2).

Effect of X-ray Exposure and Sodium azide (SA) on Plant Height

The Analysis of Variance (ANOVA) showed significant difference for plant height at $P < 0.05$, with the seeds exposed to X-ray for 10sec recorded the highest plant height of 18.13, 31.27, 49.67 and 232.63 at 2, 4, 6 and 8 weeks after sowing respectively while those treated with SA0.01% recorded the least plant height of 6.79 and 40.17 at 2 and 6 weeks after sowing while sodium azide SA0.02% treatments recorded the least plant height 17.50cm and 190.27cm at 4 and 8 weeks after sowing respectively (Table 3).

Effect of X-ray Exposure and Sodium azide (SA) on Days to 50% tasselling, 50% silking, Number of cob per plot, Number of rows per Cob and Cob length

The Analysis of Variance showed significant difference at $P < 0.05$ for Days to 50% tasselling, and silking, Number of cob per plot, Number of rows per cob, and Cob length. All the seeds treated with sodium azide took shorter days to commenced tasselling and silking earlier than the other treatments and the control. It took 55 and 63 days for seed treated with SA0.03% to commenced tasselling and silking respectively, while it took 63 and 70 days for seeds exposed to X-ray for 15 sec commenced tasseling and silking respectively. Number of cob per plot, number of rows per cob and cob length also showed variation across the treatments, seed exposed X-ray for 15 sec recorded the highest number of cob per plot and number of rows per cob of 5 and 13 respectively while those treated with SA0.02% recorded the highest cob length of 14cm, while the lowest cob per plot, rows per cob and cob length of 2, 9 and 11cm respectively was produced by the seed treated with SA0.03%. (Table 4).

Effect of X-ray Exposure and Sodium azide (SA) on Seed yield per plot, 1000 seed weight, and seed yield in Kg ha⁻¹

One of the most important characters in any breeding program is grain yield. From this research, the Analysis of variance showed difference at $P < 0.05$ for seed yield per plot, one thousand seed weight and seed yield in Kg ha⁻¹. The seed exposed to X-ray for 15 sec produced the seed yield per plot, one thousand seed weight and seed yield in Kg/ha of 325g 217 g and 543.8 kg/ha respectively, which the seed treated with sodium azide SA0.03% performed poorly in the character listed above in (Table 5).

Table 1: Effect of X-ray Exposure and Sodium azide (SA) on Days to First Germination and Germination percentage

Treatment code	Treatments	DFG	GER%
T1	SA0.01%	5.33 ^a	25.00 ^{bc}
T2	SA0.02%	5.00 ^{ab}	10.41 ^c
T3	SA0.03%	5.33 ^a	12.50 ^c
T4	X-ray5Sec	4.33 ^{bc}	63.83 ^a
T5	X-ray10Sec	3.33 ^d	72.91 ^a
T6	X-ray15Sec	4.33 ^d	50.00 ^{ab}
T7	Control	3.33 ^d	50.00 ^{ab}
	± SEM	0.39	11.71

Means followed by same superscript alphabet within the same column and treatments are not significantly different from each other at $P \leq 0.05$ (DMRT).

***= highly significant at $P < 0.001$ **= significant at $P \leq 0.01$ *= significant at $P \leq 0.05$

NS= not significant

DFG=days to first germination, GER% Germination percentage.

Table 2: Effect of X-ray Exposure and Sodium azide (SA) on Number of Leaves at 2, 4, 6 and 8 weeks after sowing

Treatment code	Treatments	NL2W	NL4W	NL6W	NL8W
T1	SA0.01%	3.70 ^{bc}	5.17 ^d	8.77 ^a	10.30 ^a
T2	SA0.02%	3.27 ^c	5.00 ^d	8.70 ^a	11.00 ^a
T3	SA0.03%	3.43 ^{bc}	5.17 ^d	8.77 ^a	10.50 ^a
T4	X-ray5Sec	4.53 ^{ab}	8.07 ^{bc}	8.47 ^a	11.20 ^a
T5	X-ray10Sec	5.53 ^a	10.07 ^a	9.40 ^a	11.87 ^a
T6	X-ray15Sec	4.47 ^{ab}	8.53 ^b	8.27 ^a	11.07 ^a
T7	Control	4.53 ^{ab}	7.60 ^c	9.40 ^a	11.20 ^a
	± SEM	0.34	0.23	0.53	0.59

Means followed by same superscript alphabet within the same column and treatments are not significantly different from each other at $P \leq 0.05$ (DMRT).

***= highly significant at $P < 0.001$ **= significant at $P \leq 0.01$ *= significant at $P \leq 0.05$

NS= not significant

Table 3: Effect of X-ray Exposure and Sodium azide (SA) on Plant Height at 2, 4, 6 and 8 weeks after sowing

Treatment code	Treatments	PLH2WAS	PLH4WAS	PLH6WAS	PLH8WAS
T1	SA0.01%	6.79 ^b	18.37 ^c	40.17 ^a	191.10 ^a
T2	SA0.02%	7.50 ^b	17.50 ^c	46.30 ^a	190.27 ^a
T3	SA0.03%	6.89 ^b	20.50 ^{bc}	46.67 ^a	218.40 ^a
T4	X-ray5Sec	16.00 ^a	27.73 ^{ab}	41.67 ^a	225.07 ^a
T5	X-ray10Sec	18.13 ^a	31.27 ^a	49.67 ^a	232.63 ^a
T6	X-ray15Sec	14.80 ^a	30.73 ^a	41.07 ^a	238.17 ^a
T7	Control	13.83 ^a	27.87 ^{ab}	42.00 ^a	230.07 ^a
	± SEM	1.67	2.25	6.16	26.86

Means followed by same superscript alphabet within the same column and treatments are not significantly different from each other at $P \leq 0.05$ (DMRT).

***= highly significant at $P < 0.001$ **= significant at $P \leq 0.01$ *= significant at $P \leq 0.05$

NS= not significant

Table 4: Effect of X-ray Exposure and Sodium azide (SA) on Days to 50% tasselling, 50% silking, Number of cob per plot, Number of rows per Cob, Cob length

Treatments code	Treatments	D50% T	D50% S	N/COBPP	NR/COB	COBL(CM)
T1	SA0.01%	56.33 ^b	63.33 ^c	2.67 ^{bc}	12.60 ^a	13.76 ^{ab}
T2	SA0.02%	57.00 ^b	64.00 ^c	2.00 ^c	9.00 ^c	14.17 ^a
T3	SA0.03%	55.3 ^b	63.00 ^c	1.67 ^c	9.43 ^c	10.59 ^d
T4	X-rays5Sec	62.00 ^a	70.33 ^{ab}	4.33 ^a	11.17 ^b	12.56 ^{abc}
T5	X-ray10Sec	60.00 ^a	71.33 ^a	5.00 ^a	12.73 ^a	13.36 ^{ab}
T6	X-ray15Sec	62.67 ^a	70.00 ^{ab}	5.00 ^a	12.63 ^a	11.04 ^{cd}
T7	Control	62.00 ^a	69.33 ^b	4.67 ^a	12.23 ^{ab}	12.29 ^{bcd}
	± SEM	1.31	0.84	0.89	0.57	0.86

Means followed by same superscript alphabet within the same column and treatments are not significantly different from each other at $P \leq 0.05$ (DMRT).

***= highly significant at $P < 0.001$ **= significant at $P \leq 0.01$ *= significant at $P \leq 0.05$

NS= not significant

Days to 50% tasselling (D50%T)

50% silking (D50%S)

Number of cob per plot (N/COBPP)

Number of rows per Cob (NR/COB)

Cob length (COBL)

Table 5: Effect of X-ray Exposure and Sodium azide (SA) on Seed yield perplot (SYPP), 1000 seed weight (1000SW), and seed yield in Kg/ha (SYKg/ha)

Treatments code	Treatments	SYPP	1000SW	SYKg/ha
T1	SA0.01%	71.51 ^{bc}	111.11 ^c	118.95 ^{bc}
T2	SA0.02%	38.53 ^{bc}	143.90 ^{bc}	64.17 ^{bc}
T3	SA0.03%	25.93 ^c	115.89 ^c	43.22 ^c
T4	X-ray5Sec	128.75 ^{bc}	178.85 ^{ab}	213.94 ^{bc}
T5	X-ray10Sec	325.08 ^a	217.08 ^a	543.78 ^a
T6	X-ray15Sec	151.41 ^a	190.60 ^{ab}	252.33 ^b
T7	Control	35.36 ^{bc}	184.46 ^{ab}	225.61 ^{bc}
	± SEM	0.57	23.056	89.68

Means followed by same superscript alphabet within the same column and treatments are not significantly different from each other at $P \leq 0.05$ (DMRT).

***= highly significant at $P < 0.001$ **= significant at $P \leq 0.01$ *= significant at $P \leq 0.05$

NS= not significant

IV. DISCUSSION

The Analysis of variance revealed significant difference for days to first germination and germination percentage, it took the maize seeds irradiated with X-ray for 10 sec 3 days shorter days for the radical to appear on the surface of the soil compared with the other treatments and the control, the effect X-ray on days to germination and germination rate, suggest that, exposing maize seeds to X-ray treatments for a certain length of time at least (10 sec) prior to planting demonstrated a stimulatory effect on the embryo leading to faster germination, while sodium azide treated seeds showed delayed germination and in higher doses inhibit germination completely. Germination in plant may be as a result of the interaction between genes and the environment, the fastest germination recorded in seeds irradiated with X-rays for 15 sec may be attributed to the effect of X-ray on the genes controlling germination in maize, Akinyosoye, (2021) carried out a study on the Effect of Sodium Azide (NaN_3) on Seed Germination and Callus Induction in Some Maize (*Zea mays* L.) Varieties reported that as the concentrations of NaN_3 increased, the percentage germination decreased from 67.2% to 46.6% in 0.01% to 0.04% NaN_3 applications respectively.

The result further revealed significant difference for number of leaves and plant height with the seeds exposed to with X-ray for 10sec recorded the highest number of leaves and plant height, these may be attributed to the fact that maize seeds exposed to X-ray treatment for 10 sec prior to planting might have induced polyploidy in its chromosomes which resulted in high vegetative growth of the plants, as polyploids has high vegetative growth compared with the normal diploid plants, while sodium azide might have probably induced monoploid in the chromosomes which affected the growth of the plant making it stunted compared with the control. Studies by Boureima *et al.* (2009) and Ali *et al.* (2015) indicated that low X-ray radiation dose significantly influenced growth parameters of crops such as sesame and cabbage.

The results further revealed significant difference for days to 50% tasselling, days to 50% silking, Number of cob per plot, Number of rows per cob, and Cob length. All the seeds treated with sodium azide took fewer days to begin tasselling and silking compared with the other treatments and the control, while X-ray exposure for 15 sec has resulted in an increase in number of cob per plot, number of rows per cob, and cob length. As mention earlier, the effect of sodium azide has resulted to reduction in the days to tasseling and silking,

these suggests that Sodium azide treatment, has affected the gene controlling tasselling and silking in maize by reducing the number of days it normally takes the plant to tasseled and silked, such mutagenic treatments can be utilize in breeding for early maturing maize varieties.

One of the most important characters in any breeding program is grain yield. From this research, the Analysis of variance showed significant difference at $P < 0.05$ for seed yield per plot, one thousand seed weight and seed yield in Kg/ha. The seed exposed to X-ray for 15 sec yielded the highest seed yield per plot, one thousand seed weight and seed yield in Kg/ha while those treated with sodium azide SA0.03% performed poorly in the characters listed above. The better performance of plants treated with X-ray for 15 sec in this research suggests that exposing maize seed to X-ray for 15sec prior to planting can help enhance the yield and yield attributing characters in maize and such characters can be utilize in breeding program aim at enhancing the yield of maize. The effect of X-ray in enhancing yield characters of maize has been reported by several researchers across the globe, for example Emmanuel Mbah (2022) exposed some seeds of (Oba super II) hybrid maize to X-ray effect before planting, reported longest cob length, 100 seed weight and grain yield in seed treated with X-ray compared with the control.

V. CONCLUSION

Exposing seeds of maize to the effect of X-ray for 15sec prior to planting can help enhance the germination and growth and yield character such as number of leaves, plant height, Number of cob per plot, Number of rows per cob, Cob length, seed yield per plot, one thousand seed weight and seed yield in Kg ha⁻¹, while days to 50% tasseling and silking were reduced, by exposing maize seed to Sodium azide treatment SA0.03%.

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REFERENCES

- [1] Adamu A.K and Aliyu H. (2007). Morphological effects of sodium azide in tomatoe (*Lycopersicon esculentum* Mill). *Science World Journal* 2:9-12.
- [2] Akinyosoye, S. T. (2021). Effect of Sodium Azide on Seed Germination and Callus Induction in Some Maize (*Zea mays* L.) Varieties. *Nigerian Journal of Seed Science (NJSS)* 4 (2) 66 - 75 2020.
- [3] Al Gawwad and Makka A (2009). Effect of chemical mutagens on *Mirabilis jalapa*. M.Sc. Thesis, *Floriculture, Faculty of Agriculture, Alexandria University*.
- [4] Al-Qurainy, F. and Khan, S. (2009). Mutagenic effects of sodium azide and its application in crop improvement. *World Applied Science Journal*, 6: 1589-1601.
- [5] Arulbacachandran, D., Mullainathan, L., Velu, S., Thilagavathi, C. (2010). Genetic variability, heritability and genetic advance of quantitative traits in black gram by effects of mutation in field trail. *African Journal of Biotechnology*, 9 (19): 2731 – 2735.
- [6] Boureima S, Diouf M, Slime RS, Diop T, Vandamme P, and Cagirgan M I (2009): Radio sensitivity of African sesame cultivars to gamma-rays. *Turkish Journal of Field Crops* 14(2), 181-190.
- [7] Çagirgan, M. (2001): Mutation techniques in sesame (*Sesamum indicum* L.) for intensive management: Confirmed mutants. In: *Sesame Improvement by Induced Mutations. IAEA-TECDOC-1195, IAEA, Vienna*, pp. 31–40.
- [8] El-Nashar YIA (2006). Effect of chemical mutagens (sodium azide and diethyl sulphate) on growth, flowering and induced variability in *Amaranthus caudatus* L. and *A. hypochondriacus* L. Ph.D. Thesis, *Floriculture, Faculty of Agriculture, Alexandria University*.
- [9] Emmanuel Mbah (2022). Improvement of growth yield and nutritional status of maize (*Zea mays* L.) through X-ray bombardment of seed Palar Povet 2022 59(3) 91-103.
- [10] FAO/IAEA (2015). Induced plant mutations in the genomics era. Food and Agriculture Organization of the United Nations, *Rome*. 2005; 262-265.
- [11] Food Agriculture Organization of the United Nations. *FAOSTAT Statistical Database*. FAO (2021). Available online at: <https://www.fao.org/statistics/en/> (accessed January 22, 2022).
- [12] Grote, U., Fasse, A., Nguyen, T. T., and Erenstein, O. (2021). Food Security and the Dynamics of Wheat and Maize Value Chains in Africa and Asia. *Frontiers in Sustainable Food Systems*, 4, 617009. <https://doi.org/10.3389/fsufs.2020.617009>
- [13] Hoballah, A.A. (2001): Selection and agronomic evaluation of induced mutant lines of sesame. In: *Sesame Improvement by Induced Mutations. IAEA-TECDOC-1195, IAEA, Vienna*, pp. 137–150.

- [14] Holme I. B., Gregersen P. L., Brinch-Pedersen H. (2019). Induced genetic variation in crop plants by random or targeted mutagenesis: convergence and differences. *Front. Plant Sci.* 10:1468. 10.3389/fpls.2019.01468.
- [15] IAEA. *IAEA Mutant Variety Database*. Available online at: <http://mvd.iaea.org> (accessed July 28, 2021).
- [16] Kamara, A.Y., S.U. Ewansiha, and A. Menkir. (2014). Assessment of nitrogen uptake and utilization in drought-tolerant and Striga resistant tropical maize varieties. *Archives of Agronomy and Soil Science* 60: 195–207. doi:10.1080 /03650340.2013.783204.
- [17] Marcu, D., Cristea, V. and Daraban, L. (2013). Dose dependent effects of Gamma radiation on Lettuce seedlings. *International Journal of Radiation Biology*, 89(3):219-223.
- [18] Mostafa, G.G., 2011, Effect of sodium azide on the growth and variability induction in *Helianthus annuus* L, *Intional Journal of Plant Breeding and Genetics.* 5: 76-85 <https://doi.org/10.3923/ijpbg.2011.76.85>.
- [19] Moussa, H.R. (2006). Role of gamma radiation in regulation of NO₃ level in rocket (*Eruca vesicaria* subsp *sativa*) plants. *Russian Journal of Plant Physiology*, 53:193-197.
- [20] Nura S, Adamu AK, Mu^{*}Azu S, Dangora DB, Fagwalawa LD (2013). Morphological Characterization of Colchicine-induced Mutant in Sesame (*Sesamum indicum* L.). *Journal of Biological Sciences* 13:277-82.
- [21] Roychowdhury R, Tah J. (2011). Chemical mutagenic action on seed germination and related seed-derived explants through colchicine treatments in *Catharanthus roseus* (L.) G. Don.
- [22] Shiferaw, B., Prasanna, B., Hellin, J., and Banziger, M. (2011). Crops that feed the world 6. Past successes and future challenges to the role played by maize in global food security. *Food Security*, 3, 307–327. <https://doi.org/10.1007/s12571-011-0140-5>.
- [23] Shu Q. Y., Forster B. P., Nakagawa H. (2012). Plant Mutation Breeding and Biotechnology. *CAB International and FAO*.
- [24] Wongpiyasatid A., S. Chotechuen, P. Hormchan, S. Ngampongsai, and W. Promcham, (2000). Induced mutations in mungbean breeding: Regional yield trial of mungbean mutant lines, *Kasetsart Journal of Natural Science.* 34: 443-449.
- [25] Wongyai, W., Saengkaewsook, W., and Veerawudh, J. (2001): Sesame mutation induction: improvement of nonshattering capsule by using gamma rays and EMS. In: *Sesame Improvement by Induced Mutations. IAEA-TECDOC-1195, IAEA, Vienna*, pp. 71–78.

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