Effect of fast neutron irradiation on agronomic traits of three tomato (*Solanum lycopersicum*) cultivars

Catherine I. OKOYE[1]*, Olamide A. FALUSI[2], Abubakar AMINU[1], Abdullahi MOHAMMAD[1] & AUDU, Muhammad Abba Isah[2]

1 Agricultural Biotechnology Department, National Biotechnology Development Agency, P.M.B. 5118, Wuse, Abuja, Nigeria
2 Department of Plant Biology, School of Life Sciences, Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria

Corresponding Author: **ifyokoye2255@gmail.com**

Abstract

Fast neutron irradiation (FNI) has been successfully utilized in the development of plant varieties with superior agronomic traits. This study thus, investigated the effect of different irradiation doses on some agronomic parameters of three selected tomato accessions (NG/MR/5/9/006, NG/AA/9/9/037 and NHGB/09/114). Exactly two hundred seeds of each accession were exposed to FNI obtained from an Americium-Beryllium source with a flux of 1.5×104 cm-2s-1 for 30, 60, 90 and 120 minutes, equivalent to 4 rad, 8 rad, 16 rad and 24 rad, respectively. The non-irradiated seeds served as control. The seeds were planted in experimental pots arranged in a Randomized Complete Block Design (RCBD) in three replicates. Results revealed significant differences ($p < 0.05$) in germination percentage with control having the significantly ($p < 0.05$) highest (90 %) in NG/MR/5/9/006 while NG/AA/9/9/037 and NHGB/09/114 revealed significantly ($p < 0.05$) higher germination percentage of 90 % and 83 %, respectively at 4 rad. No significant difference ($p > 0.05$) was observed in number of fruits per plant of NG/MR/5/9/006. A significant increase ($p < 0.05$) was observed in number of fruits per plant of NG/AA/9/9/037 and NHGB/09/114 at 4 rad (2.60 ± 0.60 and 4.00 ± 1.05, respectively) and 24 rad (2.60 ± 0.51 and 4.40 ± 1.12, respectively). The significantly highest weight of fruits and number of branches at fruiting were recorded at 90 minutes of exposure (16 rad) in all the accessions. NG/AA/9/9/037 had significantly higher number of seeds per fruit (107.33 ± 6.67) while no significant difference was observed in number of seeds per fruit. This study revealed significant enhancement in some growth and yield parameters of seeds exposed to fast neutron irradiation and demonstrates that fast neutron irradiation is an excellent tool for enhancing the efficiency of breeding *Solanum lycopersicum* and evolving higher yield variants through proper selection.

Keywords: Accessions, agronomic traits, fast neutron irradiation, irradiation doses, *Solanum lycopersicum*.

Introduction

Tomato (*Solanum lycopersicum L.*) belonging to the family Solanacea is native to tropical region having originated from South and Central America. It is one of the most important commercially available vegetables occupying the second place in the world of fruit market and food industries (Adeoti *et al.*, 2021). The fruit is considered valuable not only because of its great economic importance, but also for its high nutritive contents and remarkable sensory qualities. The production and consumption of tomato are constantly increasing, with more than 80 % of its production processed into other products (Ochida *et al.*, 2019).

Tomato fruits are rich in micronutrients (minerals, essential amino acids, sugars, vitamins, dietary fibre, iron, phosphorus vitamin B and C), contributing enormously to a well-balanced diet and healthy living (Adeoti *et al.*, 2021). They can be eaten directly as raw vegetable or processed into different products such as ketchup, sauce, chutney, juice, soup and puree. The fleshy berry fruit has been used extensively as a model plant for fruit ripening studies (Prashanth *et al.*, 2020), research in genetics, fruit development and disease resistance (Rothan *et al.*, 2019). According to Pronabananda *et al.* (2021), mutagenesis is an important technique for creating and developing mutants with increased agronomic traits. Fast neutron irradiation is a valuable tool for developing varieties with high agricultural qualities and huge economic values (Kolo *et al.*, 2021). It has been exploited for the improvement of yield components in many crop varieties like Chicken pea (*Cicer arientinum*) by Muhammad *et al.* (2005), Okra (*Abelmoschus esculentus*) by Hegazi and Hamildeldin (2010), Nigerian pepper (*Capsicum sp.*) by Falusi *et al.* (2012a), Lagos spinach (*Celosia argentea*) by Abubakar *et al.* (2015), and a host of other crops. It is therefore, feasible to induce genomic changes in tomato accessions using fast neutron irradiation. This could lead to the creation of notable genetic variability and will allow for the selection of desirable traits that could be used in future breeding programmes.

Materials and Methods

Source of research materials

The experimental materials comprising of three accessions of tomato (NG/AA/9/9/037, NG/MR/5/9/006 and NHGB/09/114) were obtained from the National Center for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Oyo State, Nigeria.

Seed viability and germinability test

Seed viability test was conducted before and after irradiation treatments following the method of Songsri et *al.* (2011), while seed germinability test was conducted according to Mitchell and Vogel (2012). Percentage germination was calculated as the number of germinated seeds divided by the total number of seeds planted multiplied by a hundred.

$$Germination\ (\%) = \frac{\text{number of seeds germinated}}{\text{total number of seeds sown}} \times 100$$

Irradiation of seeds

Exactly two hundred (200) seeds of each accession were exposed to fast neutron irradiation for four different irradiation exposure periods (IEPs): 30, 60, 90 and 120 minutes, equivalent to 4 rad, 8 rad, 16 rad and 24 rad, respectively. The irradiation was obtained from an Americium-Beryllium source with a flux of 1.5 × 104 cm-2s-1 situated at the Centre for Energy and Research Training (CERT), Ahmadu Bello University Zaria, Kaduna State, Nigeria. The equipment is a miniature neutron source reactor (MNSR) designed by the China Institute of Atomic Energy (CIAE) and licensed to operate at a maximum power of 31 Kw (SAR, 2005). The non-irradiated seeds served as controls.

Planting of seeds

The seed planting and management was done according to the method of Falusi and Daudu (2014). A total of 100 seeds of each accession of different time of exposure (dose) were nursed on 1 x 1 m nursery bed for 4 weeks to obtain seedlings. After the period of nursing, the seedlings were transplanted to 3.5 L plastic pots containing sandy-loamy soil at a rate of three seedlings/pot. At maturity, the plants were sprayed with pyrethroid cypermethrin at the rate of 10 to 15 Lha-1 with controlled droplet application using spinning disc sprayers to prevent insect attack. The seeds were irrigated once daily between 5:00 and 6:30 pm using bore-hole water. The pots were arranged in a randomized complete block design (RCBD) in three replicates and all agronomic practices were carried out when necessary and data on germination percentage, number of fruits/plants, weight of fruit, and number of seeds/plant and number of branches at fruiting were collected from all accessions and treatment groups in triplicates.

Data analysis

Data collected were subjected to a one-way analysis of variance (ANOVA) using SPSS version 20 and Duncan's Multiple Range Test (DMRT) was used to separate the means with significant differences. All results were considered significant at $p < 0.05$.

Results and Discussion

Germination percentages varied significantly ($p < 0.05$) at different irradiation doses (Figure 1). The highest germination percentage (90.33 %) was recorded in NG/AA/9/9/037 at 4 rad of FNI while the least germination percentage (75.00 %) was recorded in NHGB/09/114 at dose 24 rad FNI treatment. However, these values were less than the control values. Slight reductions in germination percentage was recorded with increased irradiation time. These variations observed in the germination percentage at different periods could be attributed to the effect of FNI. This is in agreement with the works of Daudu et *al.* (2012), Falusi et *al.* (2012b), Muhamune and Kothekar (2012) and Abubakar et *al.* (2017). They reported decrease trend in germination percentage with increased mutagenic concentrations/ doses. The decrease in germination observed in this study may be attributed to disturbances or changes at cellular level which could be physiological or physical or the combination of both effects (Abubakar et *al.*, 2017).

Results obtained from this study showed significant difference ($p < 0.05$) between the treated and the untreated plants in the number of fruits/plant, except in accession NG/MR/5/9/006, whose values do not differ significantly ($p > 0.05$) with the control (Table 1). The

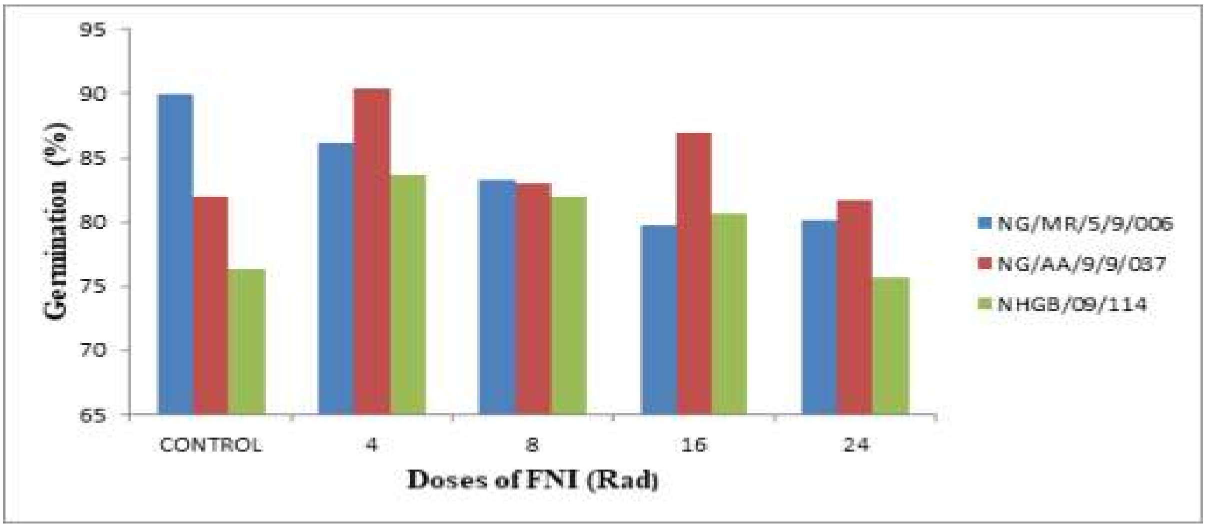

Figure 1: Effect of fast neutron irradiation on germination percentage of *S. lycopersicum*

highest number of fruits per plant (5.00) was recorded in accession NHGB/09/114 at 16 rad FNI, and a relatively high number of 4.40 and 4.00 at 24 rad and 4 rad FNI, respectively. Fast neutron irradiation produced significant higher yield in terms of number of fruits per plant, this is in agreement with the work of Kolo et *al.* (2021) who reported increased number of fruits per plant in fast neutron irradiated pepper.

Significantly higher ($p < 0.05$) fresh fruit weights were observed at 16 rad FNI exposure in the three accessions of the plant, with the highest recorded in

Table 1: Effects of fast neutron irradiation on number of fruit/plant and weight of fruit after germination of S. lycopersicum

Treatment Combinations	Number of Fruit/Plant	Weight of Fruit (g)
NG/MR/5/9/006		
Control	1.40 ± 0.24^{a}	14.32 ± 3.24^{b}
4rad	2.20 ± 0.20^{a}	19.79 ± 2.34^{c}
8rad	2.20± 0.37^{a}	12.71 ± 0.47^{a}
16rad	1.80 ± 0.20^{a}	20.08 ± 0.69^{c}
24rad	2.00 ± 0.32^{a}	15.81 ± 2.61^{b}
NG/AA/9/9/037		
Control	1.40 ± 0.24^{a}	6.86 ± 1.61^{a}
4rad	2.60 ± 0.60^{b}	9.44 ± 0.92^{a}
8rad	1.80 ± 0.37^{a}	21.42 ± 3.24^{b}
16rad	2.00 ± 0.00^{a}	24.11 ± 2.40^{c}
24rad	2.60 ± 0.51^{b}	21.18 ± 3.82^{b}
NHGB/09/114		
Control	2.00 ± 0.00^{a}	19.35 ± 2.58^{c}
4rad	4.00 ± 1.05^{b}	17.35 ± 0.24^{b}
8rad	2.80 ± 0.37^{a}	17.35 ± 0.24^{b}
16rad	5.00 ± 1.77^{c}	17.42 ± 3.49^{c}
24rad	4.40 ± 1.12^{b}	10.65 ± 5.56^{a}

Values are mean ± standard error of the mean. Values followed by the same superscript along the column are not significantly different at $p > 0.05$.

NG/AA/9/9/037 (24.11), followed by NG/MR/5/9/006 (20.08) and then NHGB/09/114 (17.42) (Table 1). These values differ significantly ($p < 0.05$) when compared with the control groups except for NHGB/09/114. This study justifies the findings of Falusi et al. (2012a) that FNI is capable of producing significant changes in the yield parameters of the pepper plant such as number of fruits and weight of fruit.

The highest number of branches at fruiting for the three accessions NG/MR/MAY/9/006, NG/AA/9/9/037 and NHGB/09/114 (8.66, 8.83, 10.50 respectively) was recorded at 16 rad FNI (Table 2). This value was significantly ($p < 0.05$) different from other FNI doses. The number of branches also increased as the FNI increased. This is similar to the report of Abdulmajeed et al. (2018)who reports increase in the number of branches per plant with increase dose of gamma irradiation.

In terms of number of seeds per fruit, accession NG/MR/5/9/006 revealed the significantly ($p < 0.05$) highest number of seeds per fruit (114.00) in the control (Table 2). However, the 16 rad FNI in accessions NG/AA/9/9/037 and NHGB/09/114 produced a relatively high number of seeds per fruit (107.33 and 102.67, respectively), which do not differ significantly ($p > 0.05$) from the control groups. The decrease observed in the number of seeds/fruits is in conformity with the findings of Amir *et al.* (2018) who reported a significant decrease in number of seeds per plant of gamma irradiated okro.

Table 2: Effects of fast neutron irradiation on number of seeds/fruit and number of branches after germination of S. lycopersicum

Treatment Combinations	NOB@FT	Number of Seeds/ Fruit
NG/MR/5/9/006		
Control	6.83 ± 0.40^{a}	114.00 ± 7.00^{c}
4rad	7.50 ± 0.42^{b}	100.33 ± 1.20^{b}
8rad	6.50 ± 0.42^{a}	86.33 ± 7.83^{a}
16rad	8.66 ± 0.71^{c}	82.67 ± 5.21^{a}
24rad	7.33 ± 0.33^{b}	90.00 ± 5.50^{a}
NG/AA/9/9/037		
Control	8.00 ± 0.25^{c}	107.00 ± 4.04^{c}
4rad	6.66 ± 0.33^{a}	99.00 ± 5.77^{b}
8rad	5.66 ± 0.49^{a}	86.33 ± 2.18^{a}
16rad	8.83 ± 0.47^{c}	107.33 ± 6.67^{c}
24rad	7.50 ± 0.99^{b}	105.00 ± 3.21^{b}
NHGB/09/114		
Control	8.00 ± 0.25^{b}	101.33 ± 15.07^{a}
4rad	5.66 ± 0.49^{a}	93.00 ± 14.17^{a}
8rad	6.25 ± 0.30^{a}	90.33 ± 8.51^{a}
16rad	10.50 ± 0.99^{c}	102.67 ± 9.27^{a}
24rad	7.33 ± 0.40^{b}	94.00 ± 11.53^{a}

Values are mean ± standard error of the mean. Values followed by the same superscript along the column are not significantly different at $p > 0.05$.
NOB - Number of Branches, FT - Fruiting, @- At

Conclusion

FNI can be used to increase selected agronomic characters and induce beneficial variability in tomato which can be incorporated in conventional breeding for the improvement of the crop. Since all the accessions were responsive to FNI treatment, either of them could serve as the parent plant in breeding and improvement programmes, especially at 16 rad FNI or through mass propagation *in vitro.*

Recommendation

It is therefore recommended that further studies be carried out to test for the geno-toxicity of the crop and exploit those exposure periods that produced promising traits for future breeding programmes of tomato.

Declaration of interest

The authors declare that there is no conflict of interest.

References

1. Abdulajeed, A., Muhammad, Z., Ullah, R. and Ali., H (2018). Gamma irradiation I: Effect on germination and general growth characteristics of plants – A review. Pakistan Journal of Botany, 50(6), 2449-2453.
2. Abubakar, A., Falusi, O. A. and Daudu, O. A. Y. (2017). Morphological and phenotypic effects of fast neutron irradiation (FNI) on Lagos spinach (*Celosia argentea* L.) Radiation Science and Technology, 3(5), 47-53
3. Abubakar, A., Falusi, O. A., Daudu, O. A. Y., Oluwajobi, A. O., Dangana, M. C. and Abejide, D. R. (2015). Mutagenic effects of sodium azide and fast neutron irradiation on the cytological parameters of M2 Lagos spinach (*Celosia argentea var cristata L.*). World Journal of Agricultural Research, 3(3), 107-112.
4. Adeoti, O. M., Sodiq, Z., Olufemi, S. O. and Komolafe, K. A. (2021). Effects of chemical mutagen (sodium azide) on tomato grown in organic and inorganic fertilized soil. International Journal of Science and Research Archive, 02(01), 072–078.
5. Amir, K., Hussain, S., Shuaib, M., Hussain, F., Urooj, Z., Khan., W. M., Zeb, U., Ali, K., Zeb, M. A. and Hussain, F. (2018). Effect of gamma irradiation on okra (*Abelmoschus esculentus L.*). Acta Ecologica Sinica, 38(5), 363- 373.
6. Daudu, O. A. Y., Falusi, O. A., Dangana, M. C., Thomas, T., Bello, I. M. and Muhammad, L. M. (2012). Mutagenic effects of fast neutron irradiation on selected morphological characters and yield of the African long pepper (Capsicum annum var. accuminatum). International Journal of Advanced Biotechnology Research, 4(1&2), 19 -24.
7. Falusi, O. A. and Daudu, O. A. Y. (2014). The effects of fast neutron irradiation on the leaf morphology of Capsicum annumm L. International Conference on Advances in Agricultural, Biological and Environmental Sciences (AABES-2014), Dubai, United Arabs Emirate. Pp. 86-88.
8. Falusi, O. A., Daudu, O. Y. and Teixeira da silva, J. A. (2012a). Effect of exposure time of fast neutron irradiation on growth and yield parameters of *Capsicum annum* and *Capsicum frutescens*. African Journal of Plant Science, 6(9), 251-255.
9. Falusi, O. A., Daudu, O. Y. and Teixeira da silva, J. A. (2012b). Effects of fast neutron irradiation on agronomic Traits of Nigerian pepper (*Capsicum annum* L.). European Journal of Horticultural Science, 77(1), 41-45.
10. Hegazi, A. Z. and Hamildeldin, N. (2010). The effect of gamma irradiation on enhancement of growth and seed yield of okra [*Abelmoschus esculentus* (L.) Moench)] and associated molecular changes. Journal of Horticulture Forum, 2(3), 38-51.
11. Kolo, J. T., Falusi, O. A., Daudu, O. A. Y., Adebola, M. O. and Abubakar, A. (2021). Evaluation of agro-morphological and pollen parameters of M2 generation of *Capsicum annuum* exposed to fast neutron irradiation (FNI). American Journal of Plant Biology, 6(2), 34-38.
12. Mahamune, S. E. and Kothekar, V. S. (2012). Induced mutagenic frequency and spectrum of chlorophyl mutants in French bean. International Multidisciplinary Research, 2(3), 30-32.
13. Muhammad, R. K., Asfari, S. Q., Syed, A. H. and Muhammad, I. K. (2005). Genetic variability induced by gamma irradiation and its modulation with gibberellic acid in M2 generation of chickpea (*Cicera rientinum* L.). Pakistan Journal Botany, 37(2), 285-292.
14. Mitchell, R. B. and Vogel, K. P. (2012). Germination and emergence tests for predicting switchgrass field establishment. Agronomy Journal, 104(2), 458-465.
15. Ochida, C. O., Itodo, A. U. and Nwanganga, P. A. (2019). A review on postharvest storage, processing and preservation of tomatoes (*Lycopersicon esculentum* Mill). Asian Food Science Journal, 6(2), 1-10.
16. Prashanth, P. J. E., Rajesh, N., Padma, J. G., Reddy, E. C. S. and Basha, P. O. (2020). Generation of gamma irradiated mutagenized population in Solanum lycopersicum CV. Arka Vikas. Current Trends in Biotechnology and Pharmacy, 14(3), 271-278.
17. Pronabananda, D., Islam, M. M., Kabir, M. H., Islam, S. S., Islam, M. R., Jahan, M. T., Roy, P. K., Halder, R., Roy, P. K., Mamun, A. N. K. and Hossain, M. (2021). Study on the effect of gamma irradiation (Co-60) on seed germination and agronomic traits in tomato plants (*Lycopersicum esculentum L.*). Notulae Scientia Biolocae, 13(4), 11061-11061.
18. Rothan, C., Diouf, I. and Causse, M. (2019). Trait discovery and editing in tomato. The Plant Journal, 97, 73–90.
19. SAR (2005). Final safety analysis report of Nigeria research reactor-1. CERT technical report-CERT/NIRR-1/FSAR-01.
20. Songsri, P., Suriharn, B., Sanitchon, J., Srisawangwong, S. and Kesmala, T. (2011). Effects of gamma radiation on germination and growth characteristics of Physic Nut (*Jatropha curcas* L.). Journal of Biological Sciences, 11, 268-274.