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The Effect of Gamma Ray Irradiation on the Growth of the Bendy Variety of Green Okra (*Abelmoschus esculentus* L.)

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Abstract

Widely cultivated, green okra (Abelmoschus esculentus L.) is a highly profitable horticultural crop. In contrast, okra production has not shown any significant improvement. This study observed the growth of green okra (A. esculentus L.) plants using gamma rays. In this investigation, the nonfactorial Randomised Block Design (RBD) method with three replications was implemented to investigate the effect of gamma radiation on green okra (A. esculentus L.) seeds. The study examined six levels of gamma radiation: 0 Gy (control), 100 Gy, 300 Gy, 500 Gy, 700 Gy, and 900 Gy. The findings indicated that plants demonstrated a survival rate at a dose of 0 Gy. At the same age, the irradiation dose of 700 Gy resulted in the highest number of leaves, whereas the control dose of 0 Gy resulted in the lowest number of leaves. The irradiation treatment dose of 500 Gy exhibited the least flowering time, while the control dose of 0 Gy exhibited the fastest flowering time. The slowest flowering time was observed at 900 Gy. This investigation determined that, compared to other radiation levels, gamma radiation at 2 WAP exhibited substantial radiation levels. This study demonstrates the critical role of gamma radiation at 2 WAP in okra production. The results of this study can be used as a prerequisite for ensuring the highest quality offspring from the effects of gamma radiation.

Keywords: *Gamma Ray Irradiation; Green Okra (Abelmoschus esculentus L.); Mutation*

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INTRODUCTION

Egypt, Sudan, Ghana, Nigeria, Ivory Coast, Benin, Burkina Faso, Cameroon, Tanzania, Zambia, and Zimbabwe extensively cultivate green okra (*Abelmoschus esculentus* L.). Ghana, Burkina Faso, and Nigeria are the primary countries that produce okra. Nigeria extensively cultivates, distributes, and consumes okra in either its fresh form (typically boiled, sliced, or fried) or dried form. People most commonly consume the young fruit of okra and prepare it as a vegetable. Okra is highly slippery due to its high fiber and mucus content (Chabibichsan et al., 2015). This okra plant requires 80% humidity and 5-7 hours of sunlight daily (Munthe, 2019).

Optimizing the yield potential is still imperative to increase okra production. One potential method for increasing productivity is to use high-yielding superior varieties. Selection can identify the desired genotype, and mutations can generate a diverse population. Green okra (*Abelmoschus esculentus* L.) is a highly profitable horticultural commodity. Despite the high demand for green okra, production yields have remained the same. Indonesia still manages most of the okra according to market demand, only cultivating it on a small scale. In Indonesia, several okra farmers typically cultivate okra through domestic and international cooperation. Indonesia has not employed okra for industrial purposes and continues to consume it as a vegetable. Numerous Asian countries have utilized okra plants for industrial purposes (Apriliyanto & Sarno, 2019).

The fruit (young fruit) is the portion that is consumed as a vegetable. Okra fruit, due to its mucus content, is suitable for soup. Young okra fruit contains 85.70% water, 8.30% protein, 2.05% fat, 1.4% carbohydrates, and 38.9% calories per 100 grams (Nadira et al., 2009). The fruit color distinguishes two varieties of okra: red okra and green okra. Because of its outstanding nutritional value and health advantages, young okra fruit is among the most widely consumed vegetables. The primary antioxidants in okra fruit are vitamin C, vitamin E, carotenoids, and phenolic compounds in flavonoids (Werdhiwati et al., 2020).

The most recent mutant's irradiation dose depends on the plant's growth phase, size, hardness, and material. The findings indicated that a 100 Gy dose of gamma-ray radiation to Persian can cause white flowers with purple edges to turn yellow. The color of flowers can be altered to yellow by gamma ray radiation with a maximum dose of 5 Gy on grains and cereals. Gamma radiation may expose plant seeds. Radiation can penetrate plant seeds and extend to the chromosome layer, influencing the structure of chromosomes. Radiation can alter plant properties, which then trickle down to their progeny (Faridawati & Sudarti, 2022).

While the transgenic approach can only integrate a single character into the plant genome, mutation induction can produce mutants with a high degree of diversity in various selectable characters (Setiawan et al., 2015). Gamma-ray radiation has been administered to numerous plants to enhance their genetic diversity, tolerance to biotic and abiotic stresses, and the quantity and quality of their yields. One of them is tomato (Ishfaq et al., 2012). Gamma radiation significantly increases the genetic diversity of purple/green *C. blumei* in terms of the number of leaves and branches (Togatorop et al., 2016).

Gamma-ray irradiation can influence plant growth and development by altering the process's physiology, biochemistry, and genetics, as well as the morphology of cells and tissues (Rosmala et al., 2022). The application of energy, such as gamma rays, to plants, is intended to have a positive impact on the agricultural sector. By administering the appropriate dose of gamma radiation, plants can develop the desired characteristics, including high yields, early maturity, and disease resistance (Sihombing et al., 2016). The anticipated outcome is the development of superior varieties with superior fruit quality compared to the previous generation through gamma-ray irradiation at varying concentrations (Sutapa & Antha 2014). This investigation aimed to ascertain the growth of the bendy F1 variety of green okra (*Abelmoschus esculentus* L.) using gamma-ray irradiation.

METHOD

From December 2023 to May 2024, this investigation was implemented. The Centre for Isotope and Radiation Applications (PAIR), National Nuclear Energy Agency (BATAN), is located at Jl. Lebak Bulus Raya No. 49 in Cilandak-South Jakarta. Okra seeds were sent to this location. The irradiated seeds were sown in Rintis Village, Silangkitang District, Labuhanbatu Regency, North Sumatra, specifically in Dusun Suhud Barat. A non-factorial randomized block design (RAK) with three replications was implemented. The experiment employed a single factor, gamma rays, to treat green okra (*Abelmoschus esculentus* L.) seeds at six treatment levels: control (0 Gy), 100 Gy, 300 Gy, 500 Gy, 700 Gy, and 900 Gy. This investigation included four sample plants in each treatment, resulting in 72 plants.

ANOVA (analysis of variance) was employed to analyse the observation data statistically. The observed characters are further tested using Duncan's Multiple Range Test (DMRT) at the <0xC8> = 0.05 level if there is a significant difference. The vegetative and generative characteristics of green okra plant growth were observed. In vegetative characters, precisely the number of leaves, plant height, and percentage of growth power. Specifically, the age of flowering applies to generative characters. According to Tefa (2017), the formula for calculating growth power is as follows:

$$\text{Growth power percentage (\%)} = \frac{\sum n}{N} \times 100\%$$

Information:
$\sum n$ = The number of seedlings grows normally
N = Total seeds planted

RESULTS AND DISCUSSION

Growth Power Percentage (%)

The okra's survival is indicative of its growth. The survival rate depends on the amount of alive, deceased, or contaminated okra. The study's findings revealed that gamma-ray induction could influence the percentage of okra survival (see in Table 1). Gamma-ray irradiation generally decreases the percentage of rosella plant survival (Wulandari et al., 2022).

Table 1 displays the average germination power of green okra seeds. The irradiation dose influences the germination power of green okra in various ways. The germination power of green okra seeds decreased by 98%, 90%, 96%, and 84% at doses of 100 Gy, 300 Gy, 500 Gy, 700 Gy, and 900 Gy, respectively, compared to 100% at a dose of 0 Gy (control). This is consistent with the findings of a study conducted by Werdhiwati *et al.* (2020), which demonstrated that the germination power of red okra seeds decreased as the irradiation dose was increased.

Table 1. Percentage of living plants after gamma ray irradiation

Dose (Gy)	Plant Percentage (%)	
	Alive	Dead
0	100	0
100	98	2
300	90	10
500	90	10
700	96	4
900	84	16

Description: Percentage of living plants and dead plants

Figure 1. Green Okra 3 Day After Planting (DAP)

Compared to seeds treated with irradiation, the 900 Gy irradiation treatment produced the highest percentage of dead plants, specifically 16%. In contrast, the percentage of dead plants was identical at 10% for irradiation doses of 300 and 500 Gy. For a dose of 100 Gy, the percentage of dead plants was 2%, and for a dose of 700 Gy, it was 4%. It is probable that the low percentage of living plants at a dose of 900 Gy is a result of chromosome damage. Harsanti & Yulidar (2019) asserted that the percentage of plant mortality will rise as the irradiation dose increases. The findings indicate that the survival of plants to adulthood is contingent upon the nature and severity of chromosome damage (Shamsiah et al., 2022). It is anticipated that gamma radiation energy can cause physical damage to cells and halt the plant's metabolic processes, thereby diminishing the outcomes of higher irradiation dose treatments (Tia, 2021). This research is consistent with the findings of Anshori *et al.* (2015), who assert that high gamma ray radiation can alter cells, particularly chromosomes and DNA, resulting in mutations that impede plant growth metabolism.

Plant Height (Cm)

Plant height measurements were initiated two weeks after planting (WAP) and were conducted every two weeks until the first flower emerged. The plant's height was determined from the soil's base to the highest leaf's tip. The analysis of variance indicated that the irradiation dose influenced the average height of okra plants for each 2-week observation. The gamma-ray irradiation factor was significantly different at 2 two weeks after planting (WAP), as indicated by the analysis of variance results (Table 2). Consequently, a DMRT (Duncan Multiple Range Test) was conducted at the 5% level (see in Table 2). Nevertheless, the gamma-ray irradiation factor did not significantly differ at 4 weeks after planting (WAP).

Table 2. Plant height after gamma ray irradiation

Dose (Gy)	2 WAP	4 WAP
0	22,69 a	47,02 a
100	20,38 b	45,04 a
300	21,11 ab	47 a
500	21,47 ab	45,6 a
700	20,17 b	43,77 a
900	16,97 c	39,74 a

Description: Numbers followed by different letters in the same column indicate significant differences based on the 5% DMRT test.

Figure 2. Green Okra on 2 WAP

At 2 WAP, the tallest plants were exposed to gamma-ray irradiation at a dose of 0 Gy (control), with an average value of 22.69 cm. The plants with the lowest height were at a dose of 900 Gy, with an average value of 16.97 cm. Additional tests confirmed this. The results of this study are consistent with Harsanti & Yulidar (2015), as soybean plants that received control treatment (0 Gy) were taller than those that received gamma-ray doses. Mutation induction substantially impacts the height and number of leaves of kara benguk plants, as gamma-ray irradiation can impede plant growth (Saragih et al., 2020). Reducing gamma-ray mutations in purple rosella can enhance the diversity of plant height in various ways. It encompasses the following: crown width, number of branches, leaf length, flowering and harvest age, wet and dry flower weight, and harvest age (Wulandari et al., 2022). According to Tah (2006) observed a decrease in the height of mung bean plants due to gamma-ray dose treatment. A dose of 40 kRad caused the most significant decrease.

Number of Leaves (Shells)

The number of leaves is one of the critical factors in plant growth because leaves are one of the essential organs of plants for photosynthesis and further development through shoots that have grown on explants. The characteristics of okra leaves are that the leaves are five-fingered, and the leaf veins are pinnate (Istiyana et al., 2019).

The number of leaves on green okra plants was observed once every 2 weeks by counting the number of leaves in each treatment. The results of the variance analysis showed that the gamma-ray irradiation factor was significantly different from the number of leaves (strands) at 2 weeks after planting (WAP) but was not significantly different at 4 weeks after planting (WAP).

Table 3. Number of leaves after gamma-ray irradiation

Dose (Gy)	2 WAP	4 WAP
0	6,5b	9,75a
100	6,58ab	10,83a
300	6,58ab	10,17a
500	7ab	10,67a
700	7,08a	11,5a
900	6,58ab	10,33a

Description: Numbers followed by different letters in the same column indicate significant differences based on the 5% DMRT test.

At the age of 2 WAP, the gamma-ray irradiation treatment with a dose of 700 Gy had the highest number of leaves, with an average of 7.08 leaves, while the dose of 0 Gy (control) had the lowest number of leaves, with an average of 6.5 leaves. Further tests revealed that the gamma-ray irradiation treatment, at a dose of 700 Gy, significantly increased the number of leaves compared to the control treatment at 2 WAP. The results of this study indicate that gamma-ray dose treatment can increase the number of leaves in green okra plants. The research of Kurniajati et al., (2020) stated that in shallot plants, gamma-ray treatment can increase the number of leaves and leaf length.

Figure 3. Measurement of the number of leaves

Flowering Age (DAP)

Flowering age is one of the most critical parameters in plant fertilization. Flowering age is one indication of plant fertilization. Okra flowers are hermaphrodite and self-compatible, with 4–8 cm diameter and 5 yellowish-white petals (Putra, 2020). The flowering age was observed by calculating the day the plant began to produce flowers ideally. The results of data analysis showed a significant effect on gamma-ray irradiation at a dose of 900 Gy on doses of 500 Gy and 0 Gy (control), presented in Figure 4.

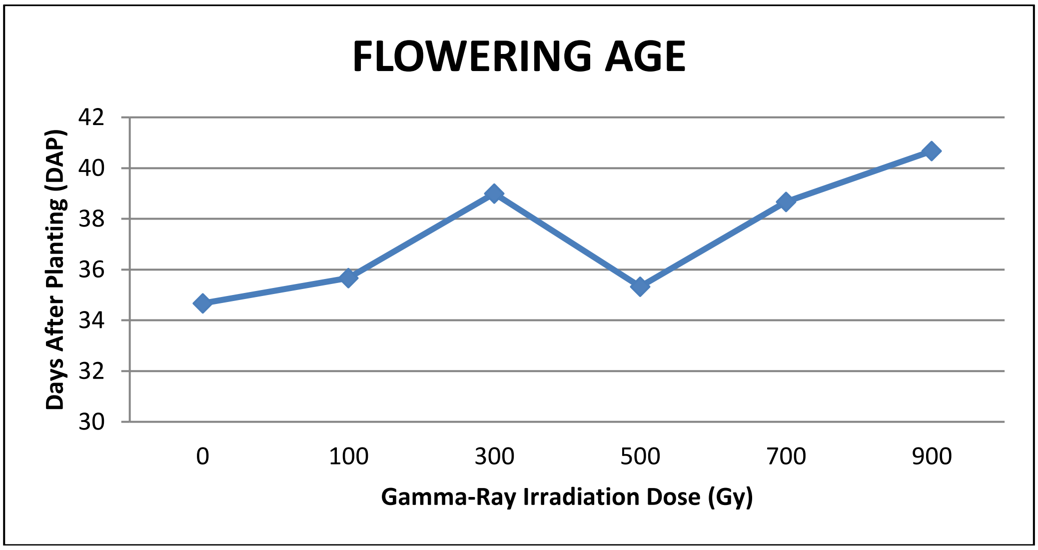

Figure 4. Flowering age graph after gamma-ray irradiation

Figure 5. Green Okra Flower

In this study, the flowering age at a dose of 0 Gy (control) was the fastest to appear flowering. Meanwhile, for the gamma-ray irradiation treatment, the fastest flower appearance was at a dose of 500 Gy, and the slowest flower appearance was at a dose of 900 Gy. This study shows that gamma-ray treatment can affect flowering age differently. This study is in line with Insani et al., (2022), who stated that high doses of gamma-ray irradiation could inhibit the flowering of tomato plants due to damage to the chromosome structure, which results in a longer flowering age.

CONCLUSION

Okra growth is based on the ability of the okra to survive. The survival percentage is influenced by the number of living okra and dead or contaminated okra. The irradiation dose affects the average height of okra plants for each observation once every two weeks. The analysis of variance showed that the gamma-ray irradiation factor was significantly different at 2 weeks after planting (WAP), so a further DMRT test was carried out at the 5% level. The number of leaves is an essential factor in plant growth because leaves are one of the critical organs of plants for photosynthesis and further development. Additional research is needed on the M2, M3, and subsequent generations to determine how gamma-ray irradiation affects the physiology and morphology of green okra plants.

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