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**RESEARCH ARTICLE** **Open Access**

# Improvement of Jangguik Rice Genotype Characters (*Oryza sativa* L. ) Through Gamma-ray Mutation Induction in the Nursery Phase

Wahyudi[1] , Elfi Indrawanis[1*] , Gusti Marlina[1]

**Abstract**

Rice is a widely cultivated and consumed food commodity. In Indonesia, the increasing population growth has led to a rise in both rice consumption and demand. The purpose of this study was to determine the effects of gamma-ray treatment on the properties of Jangguik rice, specifically regarding seed growth duration, seedling height, number of leaves, and seedling weight. The research was conducted in Koto Kari Village, located in the Kuantan Tengah District of Kuantan Senggigi Regency. The Deputy provided gamma irradiation services for Research and Innovation Infrastructure at the Yogyakarta Radiation Laboratory, situated on Jl. Babarsari, Depok, Sleman, Yogyakarta. The research was conducted over two months, from June to July 2024. This experiment employed an experimental method utilizing a Randomized Block Design with one factor. The study consisted of five treatments, each repeated three times, resulting in a total of 15 experimental plots. The treatments tested included doses of 0 Gy, 100 Gy, 200 Gy, 300 Gy, and 400 Gy. The study's results were analyzed statistically using an ANOVA table. If the calculated F-value exceeded the F-value from the table at the 5% significance level, further analysis was conducted using the Honestly Significant Difference (HSD) test at the same significance level. The results of the study indicate that gamma-ray irradiation treatment exerts a multifaceted impact on the growth of Jangguik rice seedlings. The following data were collected for analysis: the parameter of seed growth days (0 Gy treatment: 3.41 days after planting; 300 Gy treatment: 6.06 cm); the number of leaves (200 Gy: 5.46 pieces); and the weight of 100 Gy seedlings (0.146 grams).

**Keywords:** Character, Gamma-Ray, Genotype, Jangguik rice, Nursery

## 1. Introduction

Rice is a major food commodity that is extensively cultivated and consumed by the Indonesian population. The outcome of rice cultivation is the provision of rice to meet the community's consumption needs. Rice is a pivotal ingredient in a wide variety of processed foods, making it a significant global component of the food industry. In response to the escalating population growth observed in Indonesia, there has been a concomitant rise in consumption and demand for rice (Hawari et al., 2022 ).

Based on data from the Central Bureau of Statistics. (2023), rice productivity in Indonesia reached 53.63 million tons of GKG in 2023. This highlight represents a decrease of 1.12 million tons of GKG, or 2.05 percent, compared to rice production in 2022, which totaled 54.75 million tons of GKG. Furthermore, Indonesia imported 356,286.2 tons of rice in 2020, 7,741.4 tons in 2021, and 429,207.3 tons in 2022. These imports are attributed to agricultural challenges that have prevented rice productivity from reaching its potential. One significant factor contributing to this low productivity is that many farmers continue to use local rice genotypes.

The author's interviews with farmers have revealed several advantages associated with Jangguik rice. These include resistance to pests and diseases, drought resistance, and a prolonged sense of satiation following consumption. Additionally, Jangguik rice can be stored in warehouse conditions for extended periods without compromising its

*Correspondence: elfisumarli@gmail.com
1) Universitas Islam Kuantan Singingi - Jl. Gatot Subroto KM 7, Kebun Nenas, Teluk Kuantan, Kabupaten Kuantan Singingi, Riau 29566, Indonesia

taste. Notwithstanding the aforementioned advantages in the field, Jangguik rice remains encumbered by certain disadvantages. Chief among these is its comparatively lower yield when cultivated in comparison to the New Superior Variety. Additionally, the plant's elevated stature renders it susceptible to toppling in windy conditions.

Therefore, breeding efforts are necessary to address the issues present in Jangguik rice. Essentially, plant breeding involves selecting plant genotypes based on the breeder's objectives. Choosing or selecting plants will be more flexible if there is broad genetic diversity in the population. To expand genetic diversity, several methods can be employed, including induced mutation, which is an effective way to enrich genetic diversity and develop new varieties by altering plant genetics using mutagens. The aim is to obtain new traits that are superior to the parent variety (Asza et al., 2022). Mutation breeding is considered better for improving only a few traits without altering most of the original plant's characteristics that are already preferred, and it requires relatively less time in the line purification process. (Hawari et al. 2022) .

Seeds in the context of agronomy must be of high quality to produce plants that can yield maximum results. Seeds that have good viability and vigor will be able to survive and germinate and produce plants that grow well in diverse and expansive fields. Growth in the vegetative phase of plants is influenced by both genetic and environmental aspects (Immawati et al., 2013). Efforts to produce plants involve the genetic modification of local varieties, which have been developed to obtain superior varieties. Mutation induction using gamma irradiation rays can increase the genetic diversity of plants (Vazilla, 2013).

Based on research conducted by Megasari and Asmuliani (2023), Gamma-ray irradiation carried out on yellow Siamese rice seeds had a significant effect on physiological changes and plant morphology. Improvement in irradiation dose reduces power sprouts and the simultaneity of growth. The 0 Gy dose yielded results of 78%; the 200 Gy dose, 70%; the 300 Gy dose, 64.5%; and a dose of 400 Gy, 31.5%. While the germination rates at doses of 0 Gy to 300 Gy yielded the same result, namely 4 days, the dose of 400 Gy took 5 days to grow. As for chlorophyll mutations, leaves obtained several types of mutations, including Albino, Chlorina, and Striata.

The purpose of this study was to determine the properties of Jangguik rice treated with gamma-rays on seedling growth days, seedling height, number of leaves, and seedling weight.

## 2. Material and Methods

The study was conducted at the Nursery House in Koto Kari Village, Kuantan Tengah District, Kuantan Senggigi Regency, with coordinates 0°32′56.1″S 101°32′49.7″E. With a temperature of 23.0–33.0 °C, air humidity of 60 - 98%, and an altitude of 300 m above sea level. Meanwhile, Gamma Irradiation Services were carried out at the Deputy for Research and Innovation Infrastructure, Yogyakarta Radiation Laboratory. Jl. Babarsari, Depok Sleman Yogyakarta. The research was conducted from June 2024 to July 2024, spanning one month.

The tools and materials used are: hoe, machete, hand sprayer, digital scales, pH meter, planting container, 60-co Radio Active gamma facility, stationery, Jangguik rice seeds, topsoil, goat manure, river sand, dolomite, and PE plastic.

This experiment was conducted using a randomized block design (RAK) with a one-factor experimental method. This experiment consisted of 5 treatments, each repeated 3 times, resulting in a total of 15 experimental plots. The treatments tried were as follows: 0 Gy, 100 Gy, 200 Gy, 300 Gy, 400 Gy.

The research results were statistically analyzed using Microsoft Excel 2010 to determine the average value and variance. In the ANOVA table. If the calculated F is greater than the F table of 5%, then continue with the BNJ (Honest Significant Difference) test at the 5% level. The data analysis model is as follows:

$$\mathbf{Yij = \mu + Ti + \square ij}$$

Where :

Yij : Observation value on experimental units in factor group i up to j

μ : Median value

Ti : Effect of treatment up to i

□ij : Effect of error (residual) on the ith treatment of the jth replication

### 2.1. Implementation of research

Before the seeds are sown, they are soaked for 12 hours. Then, the seeds are sown in a nursery tub using a nursery medium consisting of topsoil, goat manure, and river sand with a ratio of 1:1:1. Plant maintenance is carried out according to the rice cultivation procedure in the nursery phase, including irrigation by sprinkling water twice a day, namely morning and evening, weed control by manually pulling weeds using hands, pest control by fencing the nursery land using nets.

### 2.2. Observation parameters

Observation parameters consist of the following:

#### 2.2.1. Seed Growing Day (dap)

The day of seed growth is observed by examining the development of seed sprouts, specifically when they have produced radicles and plumules. Observations are conducted over 21 days during the nursery period.

#### 2.2.2. Seedling Height (cm)

Seedling height is done by measuring the seedlings from the root neck to the highest leaf height. Seedling height is measured at 21 days after planting using a meter.

#### 2.2.3. Number of leaves (blades)

The number of leaves is observed by looking at the leaves that have opened perfectly. The number of leaves is observed when the plant has reached 21 days of age after planting.

#### 2.2.4. Seed Weight (grams)

Seed weight was measured by weighing the seeds that had been cleaned of dirt and then weighed using a digital scale. Observations were made 21 days after the seeds were removed from the planting medium.

The flow diagram of this research is as follows:

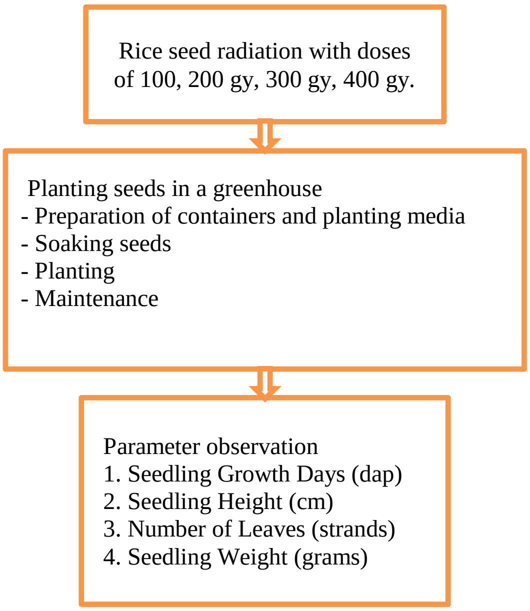


**Figure 1.** Flowchart of research on improving the genotype characteristics of Jangguik rice (Oyza sativa) L.) through gamma-ray mutation induction in the seedling phase.

## 3. Results and Discussion

### 3.1. Seed Germination Day (ds)

The observation data of the growing days of Jangguik rice seeds, after analysis of variance, showed that the gamma-ray irradiation treatment had a significant effect. The average observation results are presented in Table 1.

**Table 1.** Days of Growth of Jangguik Rice Seeds Irradiated with Gamma-rays (dap).

| Treatment | Seedling Growing Day (dap) |
|---|---|
| 0 Gy | 3.41 ± 1.63 a |
| 100 Gy | 5.16 ± 0.03 a |
| 200 Gy | 6.0 ± 0.00 a |
| 300 Gy | 7.0 ± 0.03 a |
| 400 Gy | 0.0 ± 0.00 b |
| KK= 29.35% BNJ= 5.9 | |

Note: The numbers in the columns followed by the same lowercase letters do not differ according to the Honestly Real Difference (HDR) at the 5% level.

Based on the data from Table 6, it can be observed that gamma-ray irradiation treatment has a significant impact on the growing days of Jangguik rice seeds. The fastest average growing days of seeds were observed in the 0 Gy treatment, which was 3.41 hst, and did not differ significantly from the other treatments, namely 100 Gy, 200 Gy, and 300 Gy, which were 5.16 hst, 6.0 hst, and 7.0 hst, respectively.

Based on the growth of Jangguik rice seeds, it can be observed that the higher the dose of radiation administered, the slower the growth rate. Even in the 400 Gy treatment, none of the planted seeds grew. This finding is due to the disruption of physiological activity that occurs in plant seeds. According to Lisdyayanti et al. (2019 ), the disruption of plant growth due to gamma-ray irradiation is caused by the interruption of the cell division process.

The disruption of the cell division process is caused by the disruption of growth hormone activity, a type of auxin hormone, which hampers the overall growth of the plant. This point aligns with the opinion of Jan et al. (2011). stated that giving too high a dose of irradiation can directly disrupt auxin activity that occurs in plants. This study is also in line with research conducted by Yunita et al. (2012). and ( Fiatin, 2014), who stated that gamma-ray irradiation carried out on Green Bean Seeds ( Vigna radiata L.) F3 Generation using too high a dose causes cell division to be inhibited so that it can disrupt plant growth and even cause the plants to die or not grow.

According to Lesilolo (2014), the speed of seed germination depends on the utilization of energy by each seed, which results in the breakdown of food reserves available in the endosperm. In the treatment of gamma-ray irradiation in this study, the higher the dose of gamma-ray given, the longer the seed growth rate produced, and vice versa, the lower the dose given, the faster the seed growth, as well as the development of control seeds producing seeds with the fastest speed where this is because the seeds can increase the utilization of energy from food reserves normally so that they can grow and germinate earlier.

### 3.2. Seedling Height (cm)

The observation data on the height of Jangguik rice seedlings, after analysis of variance, showed that the gamma-ray irradiation treatment had a significant effect. The average observation results are presented in Table 2.

**Table 2.** Table of Height of Jangguik Rice Seedlings Irradiated with Gamma-rays (cm).

| Treatment | Seedling Height (cm) |
|---|---|
| 0 Gy | 26.66 ± 0.03 c |
| 100 Gy | 27.33 ± 0.31d |
| 200 Gy | 20.03 ± 0.03 b |
| 300 Gy | 6.06 ± 0.06 a |
| 400 Gy | 0.00 ± 0.00 e |
| KK= 1.6% BNJ= 0.05 | |

Note: The numbers in the columns followed by the same lowercase letters do not differ according to the Honestly Real Difference (HDR) at the 5% level.

Based on the data from Table 2, it is evident that gamma-ray irradiation treatment has a significant effect on the height of Jangguik rice seedlings. The lowest average seedling height was found in the 300 Gy treatment, which was 6.06 cm, different from the 200 Gy treatment, which was 20.03 cm, different from the ) Gy treatment, which was 26.66 cm, distinct from the 100 Gy treatment, which was 27.33 cm.

Data from Table 2 show that the higher the dose of gamma-rays given, the shorter the plant height. Even at a 400 Gy treatment, no plants grew or died. This result indicates that at this dose, both physical and biological cells suffered significant damage. Disruption of the activity that occurs in the seeds, causing the plants to become shorter, does not mean that these plants are inferior. This kind of nature is the basis for a breeder to choose plant traits according to their wishes freely. The more diverse the traits that arise, the greater the chance of obtaining the desired plants, including those with short stems.

According to Dalfiansyah (2016), the impact of gamma-ray irradiation on plant diversity depends on the dose given. The higher the radiation intensity given, the higher the chance of a mutation occurring, and it can produce positive effects at specific doses.

According to Angraini (2023), the value of plant height reduction directly indicates physiological changes in plants due to radiation mutations. This highlight is caused by physical factors and biological factors that can affect the level of plant radiosensitivity to irradiation. One of the physical factors in this case is the morphology of the plant material, which involves the physical resistance of cells to gamma-ray irradiation. Genetic factors and environmental factors, such as oxygen, water content, post-irradiation storage, and temperature, are biological factors (Astuti et al., 2019).

Meanwhile, the high yields of plants produced in the 100 Gy treatment resulted in higher plant heights, even higher than those in the control treatment. This highlight is because the effect of the dose on height growth is not too dangerous. This point aligns with Siregar (2024). stated that giving a dose that is too low does not harm plants. Meanwhile, providing a dose that is too high can inhibit growth in plant height.

The high yield of seedlings produced in this study was almost the same as the study conducted by (Sari et al., 2023), namely the Effect of Irradiation on the morphological characteristics of local rice in the Pariaman field at the seedling phase where the higher the dose of gamma-rays given, the shorter the seedlings produced, namely 6.85 cm. Even at a dose of 600 Gy, none of the seeds sown grew.


**Figure 2.** Comparison of Jangguik Rice Plant Height with Gamma-ray Irradiation Treatment of 0 Gy, 100 Gy, 200 Gy, 300 Gy and 400 Gy

### 3.3. Number of leaves (blades)

Data from observations of the number of Jangguik rice leaves after analysis of variance showed that gamma-ray irradiation treatment had a significant effect. The average observation results are presented in Table 3.

**Table 3.** Table of Number of Jangguik Rice Leaves Irradiated with Gamma-rays (strands).

| Treatment | Number of leaves (blades) |
|---|---|
| 0 Gy | 5.26 ± 0.03 a |
| 100 Gy | 4.03 ± 0.03 b |
| 200 Gy | 5.46 ± 0.03 a |
| 300 Gy | 3.63 ±0.03 c |
| 400 Gy | 0.00 ± 0.00 d |
| KK= 1.2% BNJ= 0.2 | |

Note: The numbers in the columns followed by the same lowercase letters do not differ according to the Honestly Real Difference (HDR) at the 5% level.

Based on the data from Table 3, it is evident that gamma-ray irradiation treatment has a significant impact on the number of leaves of Jangguik rice plants. The average number of leaves that is highest is found in the 200 Gy treatment, which is 5.46 leaves, which is not different from the 400 Gy treatment, which is 5.26 leaves, distinct from the 100 Gy treatment, which is 4.03 leaves, and different from the 300 Gy treatment, which is 3.63 leaves.

The average number of leaves in this study indicates that the higher the dose of gamma rays given, the fewer leaves are produced. Even in the 400 Gy gamma-ray treatment, the number of leaves on rice seedlings was not available because the seedlings only grew a few and died before the measurement period for the number of leaves was carried out. Brown and dry leaves on new leaves and previous leaves characterize leaves that die due to the effects of irradiation. In the study by Natawijaya et al.

(2009), leaves that die due to the effects of irradiation are characterized by brown and dry leaves. This result occurs because irradiation can degrade chlorophyll in the leaves, thereby interfering with the photosynthesis process and ultimately leading to death.

However, when viewed from the irradiation treatments of 200 Gy, 100 Gy, and the control treatment, the number of leaves obtained tends to fluctuate. This assertion aligns with Saragih et al. (2020), who stated that mutation using gamma-ray radiation is one type of artificial radiation that can be used to increase genetic diversity because the mutations caused will be random or occur randomly in the genetic material used. This claim was also conveyed by (Dalfias(yah, 2who stated that mutations have unpredictable properties and even the genetic properties that appear are unstable in the next generation. According to Adelia et al. (2015), the interaction of gamma-rays with chromosomes can cause damage to the chromosome structure, break it, or alter its partners. The changes that occur can affect the properties of plants which is irradiated. New properties that emerge can vary; they can be better or worse, depending on the situation.

The number of leaves produced in this study is also almost the same as the study conducted by ( Herlina and Julsento, 2024), where the leaf area on the growth of M7 generation fragrant Mentik rice produced also fluctuated, the higher the dose of gamma-rays given, the narrower the leaf area produced will be, vice versa, the lower the dose given, the leaf area given will also increase.

### 3.4. Seed Weight (grams)

The observation data on the weight of Jangguik rice seedlings, after analysis of variance, showed that the gamma-ray irradiation treatment had a significant effect. The average observation results are presented in Table 4.

**Table 4.** Table of Weight of Jangguik Rice Seeds Irradiated with Gamma-rays (grams).

| Treatment | Seed Weight (grams) |
|---|---|
| 0 Gy | 0.143 ± 0.01 a |
| 100 Gy | 0.146 ± 0.01 a |
| 200 Gy | 0.143 ± 0.01 a |
| 300 Gy | 0.120 ± 0.00 b |
| 400 Gy | 0.00 ± 0.00 c |
| KK= 12.8% BNJ= 0.01 | |

Note: The numbers in the columns followed by the same lowercase letters do not differ according to the Honestly Real Difference (HDR) at the 5% level.

Based on the data from Table 4, it is evident that gamma-ray irradiation treatment has a significant impact on the weight of Jangguik rice seedlings. The average weight of the heaviest seedlings was in the 200 Gy treatment, which was 0.43 grams, and was not different from the 0 Gy and 100 Gy treatments, both of which were 0.143 grams. This result was different from the 300 Gy treatment, which was 0.120 grams.

The low average weight of seedlings produced in the 300 Gy gamma-ray treatment was due to the height of the plant. Additionally, the number of leaves in this study also yielded low results, which affected the weight of the seedlings produced. ( Asza et al. 2022) stated that the weight of a plant shows plant growth as an accumulation of the plant assimilation process and indicates plant growth. The higher the weight of the plant, as noted in the organs in the seedlings, growing well, this proves that the seedling is developing well. However, if the plant experiences abnormal symptoms, it will be reflected in the organs that are formed, which are also less than perfect, resulting in a decrease in plant weight.

The weight of the seedlings produced in this study shows that the higher the dose of gamma rays given, the lighter the weight of the seedlings produced. This claim is inseparable from the disruption of the metabolic process that occurs in a plant. Wuladari et al. (2018) stated that excessive gamma-ray doses disrupt physiological processes, resulting in a decrease in plant production, including the weight of the plants produced.

Based on the weight of the seeds produced in this study, the results were the same as the research conducted by (Sholikhah et al. 2024), where it can be concluded that the use of low-dose gamma radiation has various benefits, including increasing the growth of plant seedlings and seed germination, improving respiratory cells, increasing enzyme activity, and increasing the production of plant structures. Meanwhile, with doses that are too high, gamma radiation can interfere with plant growth. In rice plant growth, the dose of Gamma radiation used varies according to the type of rice plant. Rice types of Sileso Cultivar Generation M-2, Siam Kuning rice, local Aceh rice cultivar Sileso generation M1, Ramos variety rice, and local Ase Banda rice experienced the best growth with a Gamma radiation dose of 300 Gy. Sintanur variety rice experienced the best growth with a dose of 500 Gy. Upland rice experienced the best growth with a dose of less than 408 Gy. The Mentik Susul variety of rice underwent effective genetic changes with radiation doses of 100 Gy and 200 Gy. The local rice variety SiGadis exhibited the fastest seed germination with a radiation dose of 300 Gy.

## 4. Conclusion

Based on the study's results, it can be concluded that gamma-ray irradiation treatment has various effects on the growth of Jangguik rice seedlings. In terms of seed growth duration, the 0 Gy treatment resulted in an average of 3.41 days after sowing (hst). The seedling height for the 300 Gy treatment was measured at 6.06 cm, while the number of leaves for the 200 Gy treatment averaged 5.46 strands. Additionally, the seedling weight for the 100 Gy treatment was recorded at 0.146 grams.

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