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Applying Gamma Ray Radiation on Ciherang Rice Plants (*Oryza sativa* L.) Growth

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Abstract
The Ciherang rice variety, favored by farmers for its high productivity and resistance to several diseases, has recently shown a decline in performance due to environmental stress and suboptimal adaptation to climate change. This study aimed to determine the extent to which gamma ray exposure affects the growth of Ciherang rice plants. The research employed an experimental method using a single-factor Completely Randomized Design (CRD) with 10 treatments: 0, 50, 100, 150, 200, 250, 300, 350, 400, and 450 Gy, each repeated three times. Consequently, 30 experimental units were established and analyzed using analysis of variance (ANOVA) with SPSS software, followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level. The results demonstrated that gamma-ray radiation significantly affected plant growth and development, with responses varying according to the administered dose. Notably, the 100 ash treatment consistently outperformed others across the three measured parameters: it exhibited the highest germination rate (71%), the most significant plant height at all observation intervals (21.2 cm at 2 weeks after planting [WAP], 51.33 cm at 4 WAP, and 88.33 cm at 6 WAP), and the highest number of tillers (3.66, 6.66, and 14 tillers at the respective time points).

Keywords: Ciherang Variety, Gamma Radiation, Mutation, Plant Growth

1. Introduction

Rice (*Oryza sativa* L.) is a major food crop and a staple carbohydrate source for much of the population in Asia, including Indonesia. According to the Central Statistics Agency (BPS), in 2024, the national rice harvest area is projected to reach approximately 10.05 million hectares, representing a decrease of 167,250 hectares, or 1.64 percent, compared to the previous year. National rice production for the same year is estimated at 52.66 million tons of dry milled grain (GKG), a decline of 1.32 million tons, or 2.45 percent, compared to the 2023 production of 53.98 million tons of GKG. This reduction in rice production is attributed to several factors, including pest and plant disease infestations, climate change leading to weather instability, and the degradation of long-cultivated superior varieties. The Ciherang rice variety, favored by farmers for its high productivity and resistance to several diseases, has begun to show a decline in performance due to environmental pressures and suboptimal adaptation to climate change. Therefore, efforts are necessary to enhance the quality and resilience of this variety through scientific methods, such as using gamma ray radiation to induce mutations that may yield new varieties with superior traits.

Rice (Oryza sativa L.) is a major food crop and a staple carbohydrate source for much of the population in Asia, including Indonesia. As a strategic commodity, rice plays a crucial role in maintaining national food security. This crop thrives in tropical regions with adequate water availability, particularly in irrigated rice fields. In the Indonesian agricultural system, rice is cultivated intensively almost year-round, with various superior varieties released (Masganti et al., 2023), one of which is the Ciherang variety. Farmers in Indonesia widely cultivate the Ciherang variety due to its high productivity and relatively short harvest period, which is approximately 110–115 days after planting. This variety is known for its short plant stature, resistance to lodging, and ability to produce high-quality grain with substantial yields. Additionally, the rice is favored by the community for its soft texture and mild aroma. The Ciherang variety has also adapted well to irrigated rice fields, demonstrating relatively stable yields across various regions. Consequently, this variety is the

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preferred choice in agricultural intensification programs (Meliawati et al., 2023).

However, despite its many advantages, Ciherang rice still faces several significant challenges. One of the main weaknesses of this variety is its susceptibility to several diseases, such as blast (Pyricularia oryzae) and bacterial leaf blight (Xanthomonas oryzae), primarily if cultivated continuously without variety rotation. Furthermore, there are indications of long-term productivity decline due to genetic degradation resulting from uncontrolled seed propagation. Changing environmental conditions, such as extreme temperatures and erratic rainfall, also make this variety less stable on marginal land. These problems drive the need for genetic improvement through plant breeding innovations, one of which is the use of artificial mutation techniques, such as gamma ray radiation, to produce more resistant and productive varieties (Rosalina & Nirwanto, 2021).

Gamma radiation is a type of high-energy electromagnetic radiation often used in plant breeding to create new genetic variations. This technique works by exposing plant seeds, tissues, or organs to specific doses of a gamma ray source such as Cobalt-60. Gamma ray exposure can cause random genetic mutations in plant DNA, thus hopefully producing plants with superior traits such as disease resistance, tolerance to environmental stress, or increased productivity. In the context of the Ciherang rice variety, gamma ray radiation is used to enhance genetic traits that have begun to decline due to degradation or to increase genetic diversity in efforts to breed new varieties (Hartati et al., 2022).

However, the use of gamma radiation also poses several issues that require attention. High-dose exposure can inhibit plant growth, disrupt cell division, and even cause permanent damage to plant tissue. Uncontrolled mutagenic effects can lead to undesirable traits such as stunted growth, abnormal leaves, or decreased reproductive ability. Furthermore, not all mutations are stable or easily passed on to the next generation. Therefore, it is crucial to determine the optimal dose that can stimulate the emergence of positive mutations without causing excessive physiological damage to the plant, thereby enabling the selection process to produce genetically and agronomically superior individuals (Saputra et al., 2021). According to Manjusha et al. (2025), the duration of gamma irradiation and the radiation intensity determine the morphological and biochemical changes in plants. The inhibitory effect may be because higher doses of gamma irradiation produce biological damage more rapidly, while lower concentrations increase enzymes and growth hormones, which are responsible for the quality characteristics.

Based on the problems previously described, namely the decline in productivity and resilience of the Ciherang rice variety due to genetic degradation and its susceptibility to disease and environmental changes, researchers will conduct a study entitled "The Effect of Gamma Ray Radiation on the Growth of Ciherang Rice Variety Plants." This study was conducted to determine the extent to which gamma ray exposure can affect the growth of Ciherang rice plants.

2. Material and Methods

2.1. Place and Time of Research

The research was conducted at the Irradiation and Instrumentation Laboratory on Lebak Bulus Raya Street, Jakarta, with coordinates 6°17′21″ S, 106°46′30″ E at an altitude of 42 m above sea level and on Sempurna St., Bakaran Batu, Rantau Selatan District, Labuhanbatu Regency, North Sumatra, with coordinates 2°4′33.6″ N, 99°50′34.8″ E at an altitude of 26 m above sea level. The research was conducted from May to July 2025.

2.2. Research Tools and Materials

The materials used in this study were Ciherang rice seeds, black soil, and compost. The tools used in this study were a 4000 A gamma chamber, polybags, digital scales, a measuring tape, stationery, and a camera.

2.3. Research methods

The research method employed was an experimental design using a single-factor Completely Randomized Design (CRD), consisting of 10 treatments: 0, 50, 100, 150, 200, 250, 300, 350, 400, and 450 Gy, with each treatment repeated three times. Thus, 30 experimental units were obtained for observation.

2.4. Research Implementation

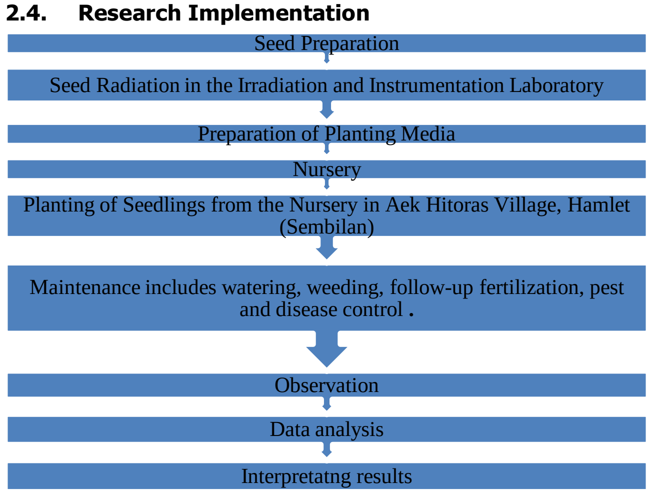

Figure 1. Research flow diagram

2.5. Research Parameters

The observations recorded in this experiment were germination percentage (%), plant height (cm), and number of shoots (strands).

2.6. Data analysis

The effect of the treatment was analyzed using analysis of variance (ANOVA) using SPSS software version 25, and if the results of the F test at the 5% level provided a significant difference, then to find out which treatment provided the best results, the data analysis was continued with the DMRT test at the 5% level.

3. Results and Discussion

3.1. Germination Power (%)

Based on field observations and analysis of germination power in the growth of Ciherang variety rice seeds, the results are presented in Figure 2. Based on the germination data of Ciherang rice variety seeds, it is evident that gamma ray radiation treatment has varying effects on the seeds' ability to germinate. The 100 grey treatment produced the highest germination rate, at 71%, followed by 150 grey (63%) and 50 grey (61%), indicating a stimulating effect at low to moderate doses. Conversely, at high doses, such as 400 grey (20%) and 450 grey (31%), germination decreased drastically, indicating physiological and genetic damage to the seeds due to excessive radiation. These results indicate that gamma radiation at specific doses can increase seed viability, but doses that are too high negatively impact the seeds' ability to grow into normal seedlings. According to Layek et al. (2022), the LD50 value, based on the germination percentage, was 181.85 Gy. The GR50 values for various cultivar sprout parameters were 176.32 Gy for germination percentage, 152.45 Gy for shoot length, 213.25 Gy for root length, 173.45 Gy for number of leaves, 171.86 Gy for fresh weight of sprouts, and 193.68 Gy for dry weight of sprouts. Meanwhile, according to Harding (2012), the percentage of survival of germinated seedlings from the 8th to the 14th day in laboratory conditions decreased significantly with increasing radiation doses up to 600 Gy. With increasing radiation above 300 Gy, a decrease in seedling height and survival percentage was observed in field conditions for irradiated plants from the M1 generation.

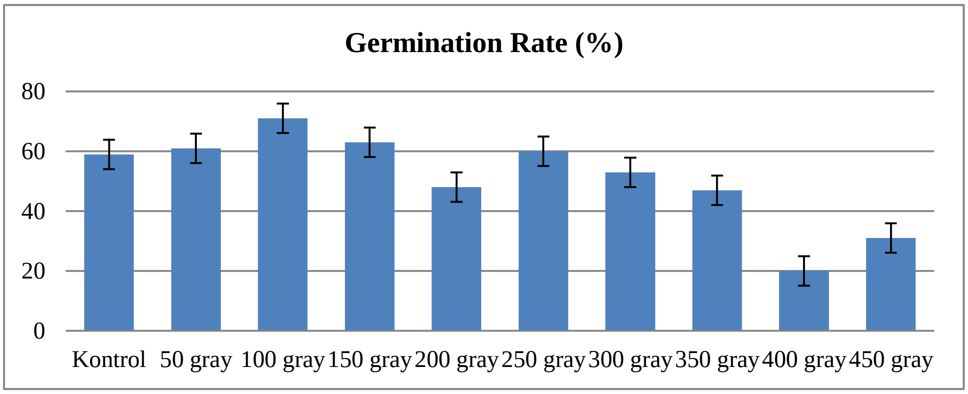

Figure 2. Results of the germination power of Ciherang rice seeds

3.2. Plant Height (cm)

Based on field observations and data analysis, the height of Ciherang variety rice plants is presented in Table 1.

Table 1. High Yield of Ciherang Rice Variety

Treatment	Plant Height (Cm)		
	2 MST	4 MST	6 MST
Control	18.83± 0.92 g	42.33± 1.70 d	79.66± 2.04 g
50 gray	20.46± 0.92 i	47± 1.70 f	85± 2.04 h
100 gray	21.2± 0.92 h	51.33± 1.70 f	88.33± 2.04 i
150 gray	19.9± 0.92 h	39.33± 1.70 f	80.33± 2.04 g
200 gray	18.13± 0.92 f	49± 1.70 f	75± 2.04 f
250 gray	17± 0.92 e	50.66± 1.70 f	71± 2.04 e
300 gray	15.53± 0.92 d	48± 1.70 f	64± 2.04 d
350 gray	14.3± 0.92 c	44± 1.70 e	59± 2.04 c
400 gray	13.1± 0.92 b	25.66± 1.70 b	49± 2.04 b
450 gray	11.9± 0.92 a	19.66± 1.70 a	41± 2.04 a

Description: Numbers followed by the same letter in the same column are not significantly different in the Duncan's distance test at level A=5% with 10 treatments and three replications.

Based on data on the height of Ciherang rice varieties at 2, 4, and 6 WAP, it appears that gamma ray radiation treatment significantly affected growth. At all observed ages, a dose of 100 grey produced the highest plant heights (21.2 cm at 2 WAP, 51.33 cm at 4 WAP, and 88.33 cm at 6 WAP), indicating a growth-stimulating effect at this dose.

Conversely, high doses such as 400 grey and 450 grey showed a drastic decrease in growth, with plant heights of only 13.1 cm and 11.9 cm at 2 WAP, and 49 cm and 41 cm at 6 WAP. This trend indicates that low to moderate doses of gamma ray radiation can enhance early plant growth, but excessively high doses negatively impact vegetative development due to potential tissue damage and disruption of physiological processes. This study is in line with (Dash & Kujur, 2024) which showed that low doses of gamma radiation (around 50–100 Gy) increased chlorophyll, flavonoid, and phenolic content compared to the control; while higher doses caused growth reduction and physiological imbalances—chlorophyll increased at 50–100 Gy, but decreased at 150–200 Gy. However, this study differs from Choi et al. (2021), which found that even low doses (100 Gy) caused DNA damage and oxidative stress, especially with long-term exposure. The leading causes of growth inhibition were decreased photosynthetic efficiency and the accumulation of reactive oxygen species, also known as free radicals.

3.3. Number of Offspring (Shells)

Based on field observations and data analysis of the growth in the number of tillers of Ciherang variety rice plants, the results are presented in Table 2.

Table 2. Results of the Number of Tillers of the Ciherang Rice Variety

Treatment	Number of Offspring (Shells)		
	2 MST	4 MST	6 MST
Control	2.33± 0.14 c	5± 0.22 e	10± 0.43 f
50 gray	3.33± 0.14 e	6± 0.22 e	12.33± 0.43 g
100 gray	3.66± 0.14 e	6.66± 0.22 e	14± 0.43 h
150 gray	3± 0.14 e	4.33± 0.22 c	11± 0.43 f
200 gray	2.66± 0.14 d	4± 0.22 b	9.33± 0.43 e
250 gray	2.66± 0.14 d	3.66± 0.22 b	8.33± 0.43 d
300 gray	2.66± 0.14 d	6.33± 0.22 e	6.66± 0.43 c
350 gray	2.33± 0.14 c	4.33± 0.22 c	5.66± 0.43 c
400 gray	1.66± 0.14 b	4.66± 0.22 d	4.33± 0.43 b
450 gray	1± 0.14 b	2.66± 0.22 a	2.66± 0.43 a

Description: Numbers followed by the same letter in the same factor column are not significantly different in the Duncan's distance test at level A=5% with 10 treatments and three replications.

Based on data regarding the number of tillers in the Ciherang rice variety at 2, 4, and 6 weeks after planting (WAP), gamma ray radiation exhibits varying effects on tiller formation. A dose of 100 grey produced the highest number of tillers at all observation stages (3.66 tillers at 2 WAP, 6.66 tillers at 4 WAP, and 14 tillers at 6 WAP), indicating its potential to stimulate tiller development. In contrast, very high doses such as 400 grey and 450 grey consistently resulted in the lowest number of tillers, with only 1 to 1.66 tillers at 2 WAP, decreasing drastically to 4.33 and 2.66 tillers at 6 WAP, respectively. This pattern suggests that low to moderate doses of gamma ray radiation can promote tiller formation, whereas high doses tend to inhibit new shoot growth, likely due to damage to meristematic cells and disruption of cell division. This study aligns with previous research, which demonstrated that low doses of gamma radiation can stimulate growth through callus induction, an analogy of tillering stimulation. A different study (Wahyudi & Indrawanis, 2025) found that radiation had no significant effect on the number of tillers. Although a 200 Gy dose slightly increased tiller number compared to the control and 100 Gy doses, this was not statistically significant. This result contrasts with low doses, which do stimulate tiller formation.

4. Conclusion

Based on the observation results, it was concluded that gamma-ray radiation had a significant effect on plant growth and development, with responses varying according to the dose administered. Notably, the 100 gray treatment demonstrated superiority across all three observed parameters: the highest germination rate (71%), the most significant plant height at all observation intervals (21.2 cm at 2 weeks after planting [WAP], 51.33 cm at 4 WAP, and 88.33 cm at 6 WAP), and the highest number of tillers (3.66, 6.66, and 14 tillers at the respective observation times).

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