Gamma Ray Irradiation On Several Rice Varieties At The Seed Germination Phase

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Abstract.

Rice (Oryza sativa L.) is a strategic food commodity and a primary source of carbohydrates for most of the world's population, including Indonesia. One effort to increase rice production is through mutation.The purpose of this study is to study the influencegamma ray irradiation on several rice varieties at the germination seedling phase. Gamma ray irradiation was carried out in January 2025 at the Center for Isotope and Radiation Applications (PAIR), National Nuclear Energy Agency (BATAN), Pasar Jumat, Jakarta, while planting was carried out on Jl. Belibis, Rantau Selatan District, Labuhanbatu Regency in March 2025. The study used a non-factorial Completely Randomized Design (CRD) namely gamma ray irradiation at the following doses: 0 Gy (control/no radiation dose); 50 Gy; 100 Gy; 150 Gy; 200 Gy; 250 Gy; 300 Gy; 350 Gy; 400 Gy and 450 Gy.Observations were made on germination rate, seedling height, and root length. The data were analyzed using analysis of variance followed by Duncan's multiple range test (DMRT). The results showed a visible effect of gamma ray irradiation on germination rate. Gamma ray irradiation also affected average seedling height and root length.The lowest reduction in germination and seedling height occurred in the Sibenang rice variety at a dose of 450 Gy, at 0%. Meanwhile, the shortest root length was in the Ciherang rice variety at a dose of 450 Gy, at 1.93 cm.

Keywords: *Irradiation; mutation; gamma rays and variety.*

I. INTRODUCTION

Rice (Oryza sativa L.) is a strategic food commodity and the main source of carbohydrates for most of the world's population, including Indonesia. Rice production in Indonesia in 2024 amounted to 52,659,237.12 tons with a harvested area of 10,046,457.29 ha, experiencing a decrease of 1,321,756.07 tons compared to rice productivity in 2023 which was 53,980,993.19 tons with a harvested area of 10,213,705.17 ha. According to the Central Statistics Agency, 2025, the decrease was due to a reduction in harvested area of 167,247.88 ha.Planting superior varieties is one way to increase rice production. One way to increase rice production is through mutation. Mutations can be achieved using two mutagens: physical mutagens using radiation and chemical mutagens. Mutation breeding aims to improve traits and introduce recessive traits from parent plants without altering most of the parent plant's traits.[1].Determining the appropriate dose can be estimated by studying radiosensitivity. Sensitivity to radiation can be measured based on the lethal dose (LD) value, which is the dose that causes death in the irradiated plant population. High doses generally only cause abnormal changes in plant phenotype. According to Soeranto (2003 in[2]), the optimum dose in mutation induction that can produce the most mutants is at LD20 and LD50.In the research[3]Regarding the LD50 study on rice using gamma ray irradiation, it was reported that the LD50 value for the Madang Pulau rice variety was 333.58 Gy, Putiah Papanai 377.62 Gy and Banang Kuning 291.14 Gy.

[4]found that gamma ray irradiation of the local rice variety SiGadis experienced the fastest seed germination at a radiation dose of 300 Gy.[5]showed that the use of gamma ray radiation technology during germination resulted in mutations and increased genetic variability.Rice is not native to Indonesia, but the Indonesian people rely on rice as a staple food crop. Rice (Oryza sativa L.) is a popular crop for Indonesians and other nations around the world. Indonesia positions rice as a staple food crop, making its cultivation crucial to understand and develop.[6]. Rice growth begins with germination. The germinating seed develops both root and stem buds. Initially, the germinating rice seedling only develops a root, then after 5-6 days,

fibrous roots develop. Rice roots are fibrous and highly effective at absorbing nutrients but are sensitive to drought. Rice roots are concentrated at a depth of 20-30 cm.Sword-shaped rice leaves are classified as narrow-leaved, and have the potential to produce many shoots.[6].Rice stalks are composed of hollow, leafy segments enclosed by nodes. Due to their clumping nature, a single planted seedling will produce new shoots or shoots within a short time.The aim of this study was to determine the effect of gamma ray irradiation on several rice varieties during the seed germination phase.

II. MATERIALS AND METHODS

Place and Time

Gamma ray irradiation was carried out in January 2025 at the Center for Isotope and Radiation Applications (PAIR), National Nuclear Energy Agency (BATAN), Pasar Jumat, Jakarta, while planting was carried out on Jl. Belibis, Rantau Selatan District, Labuhanbatu Regency in March 2025.

Materials and tools

The materials used in this study were local rice varieties (sibenang, silumat) and lowland rice (Ciherang), topsoil, rice husks, and cow manure. The tools used were a ruler/tape measure, camera, scissors, permanent marker, pen, seedbed, and label.

Research Design

This study used a non-factorial Completely Randomized Design (CRD) namely gamma ray irradiation at the following doses: R0: 0 Gy (control/no radiation dose); R1: 50 Gy; R2: 100 Gy; R3: 150 Gy; R4: 200 Gy; R5: 250 Gy; R6: 300 Gy; R7: 350 Gy; R8: 400 Gy and R9: 450 Gy. Each treatment was repeated 3 times.

Research Implementation

The seeds were placed in 10 bottles to be irradiated with gamma rays at the following doses: 0 Gy (control/no radiation dose); 0 Gy (control/no radiation dose); 50 Gy; 100 Gy; 150 Gy; 200 Gy; 250 Gy; 300 Gy; 350 Gy; 400 Gy and 450 Gy. The dose of each irradiation treatment was sown in rows of 100 seeds for each variety. The seeds were sown in a seedbed containing a planting medium of topsoil and sand with a ratio of 2:1.

Observation Parameters

The parameters observed in this experiment are:

1. Percentage of Sprouts (%)

Germination percentage (%) is a parameter often used to measure seed vigor. Germination percentage is the number of normal seedlings on the last day of the germination test and is related to the potential for normal seedlings under field conditions. Germination percentage is observed at 3 Weeks After Sowing (WAS).

2. Seedling Height (cm)

Seedling height is typically used as an indicator of genotype response to mutagens. The effect of irradiation on seedling height in this study was observed at 3 weeks after sowing (WAS).

3. Root Length (cm)

Observations of root length were carried out by measuring the base to the tip of the root at the age of 3 weeks after sowing (MSS).

Data analysis

The data from the last observation were analyzed using analysis of variance with the F test. If the calculated F of the treatment was greater than the F table of 5%, then it was continued with the Duncan Multiple Range Test (DMRT) using the STAR (Statistical Tool for Agricultural Research) software.

III. RESULTS AND DISCUSSION

Germination Percentage (%)

The results of the study showed that increasing the irradiation dose had different effects on the germination of several local rice varieties (Silumat and Sibenang) and Ciherang lowland rice (Table 1).

Table 1. Germination power of several rice plant varieties resulting from gamma ray radiation at 3 weeks after sowing (MSS)

Irradiation Dose (Gy)	Germination Power (%)		
	Silhouette	Thread	Ciherang
0	100	98	72
50	96	94	60
100	94	80	60
150	90	76	60
200	70	84	56
250	72	74	34
300	86	36	20
350	68	16	6
400	78	18	28
450	14	0	4

At a dose of 0 Gy (control), high germination power was obtained in each rice variety at 3 Weeks After Sowing (MSS). The decrease in germination power did not occur randomly at each irradiation dose. The decrease in germination power below 50% in the Silumat variety rice occurred at a dose of 450 Gy, namely 14%. In the Sibenang variety rice plant, the decrease in germination power occurred starting from doses of 300 Gy, 350 Gy, 400 Gy and 450 Gy, respectively, were 36%, 16%, 18% and 0%. Meanwhile, in the Ciherang variety rice, the decrease in germination power below 50% occurred starting from doses of 250 Gy, 300 Gy, 350 Gy, 400 Gy and 450 Gy, respectively, were 34%, 20%, 6%, 28% and 4%. This is in accordance with the results of research conducted.[7]that irradiated rice seeds have a lower growth percentage than those that are not irradiated.[8]Low plant germination is caused by gamma ray irradiation which can disrupt the plant's metabolic system.(Puspita Sari et al., 2023)stated that high doses cause greater cell damage which is indicated by a decrease in the percentage of germination.

Seedling Height (cm)

Gamma ray irradiation in this study resulted in significant diversity in seedling height at 3 Weeks After Sowing (MSS) (Table 2).

Table 2. Average seedling height of several rice varieties irradiated with gamma rays at 3 weeks after sowing (MSS)

Irradiation Dose (Gy)	Seedling Height (cm)		
	Silhouette	Thread	Ciherang
0	20.00a	18.97a	22.07a
50	18.97a	17.63a	16.07b
100	14.87b	16.63ab	14.43bc
150	14.47b	17.80a	18.83ab
200	16,17ab	14.17b	12.83c
250	12.57bc	11.93bc	8.33d
300	10.07c	3.73d	7.30d
350	9.97c	4.17d	4.60e
400	8.60c	5.70 cd	2.53f
450	11.43bc	0.00e	1.30f

Description: Numbers followed by different letters in the same column are significantly different in the 5% DMRT test.

Based on Table 2, it shows that gamma ray irradiation treatment significantly affected the seedling height of the three rice varieties, namely the silumat, sibenang, and ciherang varieties. In the silumat variety, the highest seedling height was at a dose of 0 Gy (control), namely 20.00 cm and the lowest at a dose of 400 Gy, namely 8.60 cm. For the highest seedling height of the sibenang variety, the rice was at a dose of 0 Gy (control), namely 18.97 cm and the lowest at a dose of 450 Gy, namely 0 cm. Meanwhile, in the ciherang variety, the highest seedling height was also at a dose of 0 Gy, namely 22.07 cm and the lowest at a dose of 450 Gy, namely 1.30 cm. It is suspected that gamma ray irradiation causes inhibition of the growth of rice seedlings.According to[8], the diversity of characters is caused by the effect of gamma ray irradiation mutations which causes the height of the seedlings to appear shorter than the wild type.

Root Length (cm)

Based on the results of the analysis of variance, it shows a significant effect on the root length of several rice varieties (Table 3).

Table 3. Root length of several rice plant varieties resulting from gamma ray radiation at 3 weeks after sowing (MSS)

Irradiation Dose (Gy)	Root Length (cm)		
	Silhouette	Thread	Ciherang
0	7.60bc	8.33ab	13.03ab
50	5.17d	5.77bc	10.80bc
100	6.10 cd	8.77ab	13.30ab
150	9.63ab	12.40a	14.57a
200	10.17a	8.60ab	11.93b
250	8.20b	7.87b	12,13b
300	7.70bc	2.60cd	7.83c
350	9.13ab	1.77d	4.50d
400	5.10 cd	2.53 cd	3.93d
450	4.50d	0.00e	1.93e

Description: Numbers followed by different letters in the same column are significantly different in the 5% DMRT test.

Gamma ray irradiation treatment resulted in shortening in all three rice varieties. In the Silumat variety, the highest root length was 10.17 cm at a dose of 200 Gy, and the lowest at a dose of 450 Gy, which was 4.50 cm. For the Sibenang variety, the highest root length was 12.40 cm at a dose of 150 Gy, and the lowest at a dose of 450 Gy, which was 0 cm. Meanwhile, in the Ciherang variety, the highest root length was 14.57 cm at a dose of 150 Gy, and the lowest at a dose of 450 Gy, which was 1.93 cm.[10]Changes in plant phenotype can be seen from differences in measurement results for each observed character. Irradiation causes an increase or even decrease in the value of the character measured quantitatively.[8], stated that there was a mutation effect of gamma ray irradiation which caused the root length to appear shorter than the wild type.

IV. CONCLUSION

Gamma ray irradiation affects germination power, average seedling height and root length.The lowest reduction in germination and seedling height occurred in the Sibenang rice variety at a dose of 450 Gy, at 0%. Meanwhile, the shortest root length was in the Ciherang rice variety at a dose of 450 Gy, at 1.93 cm.

V. THANK-YOU NOTE

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