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Application of Gamma-Ray Dose on Two Varieties of Sugar Palm (*Arenga Pinnata* Merr.) To Obtain the Best Growth Rate

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Abstract

The sugar palm (*Arenga pinnata* Merr.) is one of the palm species in Indonesia that offers numerous benefits. However, its slow growth until reaching a productive stage has contributed to a decline in its overall productivity over time. Gamma-ray irradiation has emerged as a potential approach to improve the genetic quality in order to enhance its productivity. This study aims to determine the optimal growth rate resulting from various doses of gamma-ray irradiation and two sugar palm varieties. The research employed a factorial Randomized Block Design (RBD). The first factor was the dose of gamma-ray radiation (B), which consisted of five levels: 0 Gy (control), 4 Gy, 6 Gy, 8 Gy, and 10 Gy. The second factor was the sugar palm variety (V), which consisted of two levels: the parasitic sugar palm and the local Lebak sugar palm. Each treatment was repeated three times, with each unit containing two plants, yielding a total of 60 seedlings. The result shows that the doses of gamma radiation, 4 Gy provide the best effects on plant height, leaf width, and number of leaves. In addition, the greenish leaves provide the best effect on the radiation dose of 6 Gy.

***Keywords**: Dose, Gamma Ray Irradiation, Genetics, Growth Rate, Sugar Palm, Varieties*

INTRODUCTION

Indonesia is well-known as an agricultural country with abundant biodiversity and great potential in various agricultural commodities development. One of the local plants which has important economic and ecological value, but it has not received full attention is the sugar palm (Arenga pinnata Merr.). It is a type of palm plant which can grow well on marginal land with its ability to easily adapt to various types of soil and it is not greedy for nutrients. According to Rosadi et al. (2019) [9], the ideal height for the growth of sugar palm plants is 0 - 1,400 meters above sea level with a fairly high adaptability to the growing environment in various ecosystems. Currently, large-scale sugar palm cultivation techniques have not been conducted by Indonesian farmers so that growth tends to be slow and productivity is low.

Sugar palm production in Banten Province is still relatively low compared to its potential. Although this area has agro-climatic conditions which support its growth, sugar palm plants are still seen as side crops by many farmers so that their management is conducted traditionally and it is not oriented towards increasing yields. Based on data from the Central Statistics Agency (BPS) of Banten Province, there has been a significant decline in palm sugar production from 2020 to 2022. In 2020, total production reached 4,035 tons, but fell to 2,828 tons in 2021, and fell drastically again to 1,569 tons in 2022. It shows the need for ongoing efforts from farmers to maintain production in order to meet the consumption needs of the community and maintain the sustainability of palm sugar productivity in Banten Province.

One of the efforts in genetic improvement of palm sugar plants is through mutation induction which is conducted by using gamma ray radiation. This technique triggers random changes in the genetic structure of plants, which can produce mutant varieties. The success rate in obtaining mutant plants is greatly influenced by the amount of irradiation dose given. Mutations can appear in all parts and at various phases of plant growth, but they are generally more common in tissues

which are actively undergoing cell division; such as, seeds and shoots. Molecularly, mutations are caused by changes in the nucleotide sequence in chromosomal DNA, which can ultimately affect the synthesis and function of the resulting protein (Kurniawan and Ariyanti, 2024)[5] .

Giving gamma ray radiation in low doses can stimulate the growth of plant seedlings, and it can accelerate the germination process by increasing the formation of plant structures, activating enzymatic reactions, and strengthening cell respiration activity. Conversely, exposure to gamma rays in high doses tends to cause negative effects that have an impact on inhibiting plant growth and development (Nuraeni et al., 2023)[7]. Therefore, it is expected that the growth rate of sugar palm plants can be increased by applying different doses of gamma rays to two sugar palm varieties.

RESEARCH METHODOLOGY

This study was conducted in October 2025 – May 2025. Gamma ray irradiation on sugar palm seeds was conducted at the Center for the Application of Isotopes and Radiation (PAIR), National Nuclear Energy Agency (BATAN), Pasar Jumat, South Jakarta. Planting of sugar palm seeds was conducted in the greenhouse of the experimental garden (6°12′07″S 106°07′31″E) of the Department of Agroecotechnology, Faculty of Agriculture, Sultan Ageng Tirtayasa University. The tools and materials used include scissors, 6.4 cm diameter plastic cups, soil sieves, hoes, sacks, tarpaulins, 35 cm x 35 cm polybags, digital scales, gloves, markers, tape, knives, sprayers, SPAD-502 Plus chlorophyll meters, upgraded Co-60 Gamma Cell 220 irradiators for irradiation treatment, cellphone cameras, stationery, red cardboard, styrofoam, logbooks, vernier calipers, rulers and meters, Parasi and local Lebak variety palm seeds, soil (top soil), rice husk charcoal and cow dung fertilizer with a ratio of 1: 1: 1. This study used a Randomized Block Design (RBD) which consisted of two factors, namely the dose of gamma ray radiation consisting of 5 levels, namely 0 Gy as the control treatment (B0), 4 Gy (B1), 6 Gy (B2), 8 Gy (B3), and 10 Gy (B4). Meanwhile, in the second factor, there were 2 levels, namely the parasitic sugar palm variety and the local sugar palm variety of Lebak. From these two factors, 12 treatment combinations were obtained, with each treatment combination repeated three times so that a total of 36 experimental units were obtained. Each experimental unit consisted of two polybags, and each polybag contained one plant seed so that the number of sugar palm seeds used was 72 seeds. In addition, the response design in this study was plant height (cm), leaf width (cm), number of leaves (strands), leaf greenness (µ/cm2), and analysis of the initial and final planting media.

A. Gamma Ray Irradiation

The sugar palm seeds were first selected to choose good-quality seeds. Seed selection was based on the size of the large seeds (more than 2 cm), not damaged, not hollow, and not wrinkled. The sugar palm seeds are given radiation doses of 4 Gy, 6 Gy, 8 Gy, and 10 Gy. Seed irradiation was carried out using the Panoramic Multi-Purpose Irradiator equipped with a Co-60 gamma source at the Center for Isotopes and Radiation Applications (CIRA), National Nuclear Energy Agency (BATAN), Pasar Jumat, South Jakarta, Indonesia.

B. Planting and Maintenance of Sugar Palm Plants (Arenga pinnata Merr.)

After irradiation, the sugar palm seeds can be planted in the planting area. Planting was conducted in the afternoon in order to prevent high evaporation if moved in the morning. The planting area used a 35 x 35 cm polybag. The growing medium used was a mixture of soil (topsoil), rice husk charcoal, and cow dung fertilizer with a

ratio of 1 1 1, and the polybag was filled with the media up to 3/4 full. Maintenance was conducted by watering once a day in the morning or evening. watering was conducted until the final weight of the polybag was achieved according to the field capacity. Meanwhile, weeding was conducted around the plants manually so that weeds do not interfere with the growth of the cultivated sugar palm plants.

C. Data Processing

The data obtained from the observation results were processed by using Microsoft Excel for Windows, in the 2-factor RBD analysis of variance test at the 5% level and further testing in this study with the Duncan Multiple Range Test (DMRT) at the 5% level.

RESULT AND DISCUSSION

The results of this study show that there is a variation in the growth rate of two varieties of sugar palm plants to the dose of gamma sonar radiation. Furthermore, based on the data obtained, the growth of two varieties of sugar palm plants is different at each dose of gamma ray radiation given. This determines the effect of the dose of gamma ray radiation on the growth rate of sugar palm plants, as shown in Table 1.

Table 1. Recapitulation of the Results of Investigation of the Variety of Gamma Ray Doses on Two Sugar Palm Varieties on the Growth of Sugar Palm Plants

No	Observation Parameters	Treatment				
		Plant Age (WAS)	Gamma Ray Dose (B)	Sugar Palm Variety (V)	Interaction	K (%)
1.	Plant Height (cm)	18	**	tn	tn	10,66
		19	**	tn	tn	10,73
		20	**	tn	tn	10,79
		21	**	tn	tn	10,09
		22	**	tn	tn	10,20
		23	**	tn	tn	10,27
		24	**	tn	tn	10,32
		25	**	tn	tn	10,37
2.	Leaf Width (cm)	18	**	tn	tn	7,28
		19	**	tn	tn	7,46
		20	**	tn	tn	7,70
		21	**	tn	tn	7,32
		22	**	tn	tn	7,29
		23	**	tn	tn	7,44
		24	**	tn	tn	7,45
		25	**	tn	tn	7,47
3.	Number of Leaves (Sheet)	18	*	tn	tn	3,58
		19	*	tn	tn	3,61
		20	**	tn	tn	3,68
		21	**	tn	tn	3,46
		22	**	tn	tn	3,44
		23	**	tn	tn	3,81
		24	**	tn	tn	3,84
		25	**	tn	tn	3,94
4.	Greenish of the leaf	20	**	tn	tn	12,32
		24	**	tn	tn	12,99

Note: * : Have a significant effect
**: Has a very significant effect
tn : Does not have a significant effect

The recapitulation of the results of the analysis of variance shows that in the gamma ray dose treatment, each parameter, namely the parameters of plant height, leaf

width, and greenness of leaf, each week has a very significant effect. The number of leaves exhibited a significant difference at 18 and 19 weeks after sowing (WAS), and a highly significant difference from 20 to 25 WAS. Meanwhile, the recapitulation of the analysis of variance in the variety treatment and the interaction between the gamma ray dose and the sugar palm variety do not provide a significant effect at 18 WAS to 25 WAS for the parameters of plant height, leaf width, number of leaves, and at 20 WAS and 24 WAS for the parameters of leaf greenness.

Plant Height (cm)

Plant height measurement was conducted to determine the growth rate of sugar palm plants by measuring from the base of the lower stem to the tip of the tallest plant using measuring tools in the form of a ruler and meter. The data obtained were then processed and further tested as shown in Table 2.

Table 2. Average Increase in Height of Sugar Palm Plants from the Effect of Gamma Ray Dose on Two Sugar Palm Varieties

Plant Age (WAS)	Gamma Ray Dose (B)	Variety (V)		Average
		V1	V2	
18	B0 (0 Gy)	0,00	9,50	4,75^{bc}
	B1 (4 Gy)	29,00	31,08	30,04^{a}
	B2 (6 Gy)	30,00	28,25	29,13^{a}
	B3 (8 Gy)	17,83	5,67	11,75^{b}
	B4 (10 Gy)	14,75	8,00	11,38^{b}
	Average	18,32	16,50	
19	B0 (0 Gy)	0,00	9,50	4,75^{bc}
	B1 (4 Gy)	29,17	31,17	30,17^{a}
	B2 (6 Gy)	30,00	28,50	29,25^{a}
	B3 (8 Gy)	18,33	6,33	12,33^{b}
	B4 (10 Gy)	14,92	8,67	11,79^{b}
	Average	18,48	16,83	
20	B0 (0 Gy)	0,00	9,50	4,75^{bc}
	B1 (4 Gy)	30,17	31,17	30,67^{a}
	B2 (6 Gy)	30,67	30,33	30,50^{a}
	B3 (8 Gy)	18,67	6,67	12,67^{b}
	B4 (10 Gy)	15,50	9,50	12,50^{b}
	Average	19,00	17,43	
21	B0 (0 Gy)	0,00	10,00	5,00^{c}
	B1 (4 Gy)	30,83	31,42	31,13^{a}
	B2 (6 Gy)	31,50	28,92	30,21^{a}
	B3 (8 Gy)	19,67	7,17	13,42^{b}
	B4 (10 Gy)	15,75	10,50	13,13^{b}
	Average	19,55	17,60	
22	B0 (0 Gy)	0,00	10,33	5,17^{d}
	B1 (4 Gy)	31,33	31,83	31,58^{a}
	B2 (6 Gy)	32,67	29,58	31,13^{a}
	B3 (8 Gy)	20,00	8,50	14,25^{ab}
	B4 (10 Gy)	16,17	11,17	13,67^{c}
	Average	20,03	18,28	
23	B0 (0 Gy)	0,00	10,33	5,17^{d}
	B1 (4 Gy)	32,17	32,00	32,08^{a}
	B2 (6 Gy)	33,00	29,83	31,42^{ab}
	B3 (8 Gy)	20,00	8,50	14,25^{ab}
	B4 (10 Gy)	17,33	11,33	14,33^{c}
	Average	20,50	18,40	
24	B0 (0 Gy)	0,00	10,33	5,17^{c}

	B1 (4 Gy)	33,33	32,33	32,83[a]
	B2 (6 Gy)	33,83	30,67	32,25[a]
	B3 (8 Gy)	20,17	9,25	14,71[ab]
	B4 (10 Gy)	18,08	11,50	14,79[b]
	Average	21,08	18,82	
25	B0 (0 Gy)	0,00	10,50	5,25[c]
	B1 (4 Gy)	33,83	33,50	33,67[a]
	B2 (6 Gy)	35,00	31,17	33,08[a]
	B3 (8 Gy)	20,50	9,67	15,08[ab]
	B4 (10 Gy)	18,42	11,67	15,04[b]
	Average	21,55	19,30	

Note: Numbers followed by the same letter in the same column indicate no significant difference in the further Duncan Multiple Range Test (DMRT) 5%.

Based on Table 2, the average height of the sugar palm plants observed for 8 weeks, it shows that the best treatment was affected by the gamma ray dose factor at a dose of 4 Gy, which was not significantly different from the dose of 6 Gy. Control plants with a dose of 0 Gy tended to show suboptimal height growth. Therefore, it shows that the administration of mutagens in the form of gamma ray irradiation with several doses resulted in differences in the height growth of sugar palm plants compared to plants without radiation or plants that are given higher dose treatments.

The average height of the tallest sugar palm plants reached 33.67 cm at the age of 25 WAS. Based on research which had been conducted by Nurmayulis et al. (2021)[8], sugar palm local lebak plants have an average height of 28.1 cm at the age of 1 year. It proves that the increase in the height of sugar palm plants at the age of less than one year is affected by mutations caused by gamma-ray radiation. Meanwhile, according to Hartati et al. (2022)[4], changes that occur in plant morphology due to radiation can be caused by the interaction of gamma rays with molecules, which can produce free radicals, so that these free radicals will trigger modifications of cell components that affect changes in plant morphology.

In contrast to the previous dose, sugar palm plants with a dose of 10 Gy show a decrease in the rate of increase in the height of sugar palm plants. It is suspected because the gamma ray dose used was too high, so that it is less suitable for the parasite variety of sugar palm plants and the local Lebak variety. It is supported by the statement of Nuraeni et al. (2023) [7], which stated that the higher the dose of gamma rays used, the lower the height of the resulting plant. The decrease in plant height can be caused since the plant chromosomes have been damaged by radiation activity, which will affect DNA and protein damage, inhibit enzyme activity, and disrupt the physiological processes of the plant.

Leaf Width (cm)

Measurement of leaf width was conducted to determine the growth rate of sugar palm plants by measuring from the right side to the left side of the widest leaf using measuring instruments in the form of a ruler and meter. The data obtained were then processed and further tested as shown in Table 3.

Based on Table 3, the average leaf width observed for 8 weeks shows that the best treatment is affected by the gamma ray dose factor of 4 Gy which is not significantly different from the dose of 6 Gy, where on average each week there is a significant increase in leaf width until the end of the observation. The average width of the highest sugar palm plant leaves at the end of the observation reached 12.75 cm, which, on average, indicates an optimal photosynthesis process in the leaves. It is in line with the results of research which had been conducted by Nurmayulis *et al.* (2021)[8], that the average width of sugar

palm local lebak leaves reached 6.8 cm with the help of photosynthate which is broken down through the respiration process and produced the energy needed by cells to enlarge cells, causing the leaf width to continue to increase

Table 3. Average Increase in Leaf Width of Sugar Palm Plants from the Effect of Gamma Ray Dose on Two Sugar Palm Varieties

Plant Age (WAS)	Gamma Ray Dose (B)	Varieties (V)		Average
		V1	V2	
18	B0 (0 Gy)	0,00	3,67	1,83^{bc}
	B1 (4 Gy)	9,00	9,25	9,13^{a}
	B2 (6 Gy)	8,33	7,80	8,07^{a}
	B3 (8 Gy)	4,33	1,72	3,03^{bc}
	B4 (10 Gy)	4,42	2,83	3,63^{b}
	Average	5,22	5,05	
19	B0 (0 Gy)	0,00	4,00	2,00^{bc}
	B1 (4 Gy)	9,33	10,38	9,86^{a}
	B2 (6 Gy)	9,50	8,72	9,11^{a}
	B3 (8 Gy)	4,33	2,05	3,19^{b}
	B4 (10 Gy)	4,92	3,50	4,21^{b}
	Average	5,62	5,73	
20	B0 (0 Gy)	0,00	4,00	2,00^{bc}
	B1 (4 Gy)	11,33	10,97	11,15^{a}
	B2 (6 Gy)	10,50	9,63	10,07^{a}
	B3 (8 Gy)	4,50	3,05	3,78^{b}
	B4 (10 Gy)	6,75	3,50	5,13^{b}
	Average	6,62	6,23	
21	B0 (0 Gy)	0,00	4,00	2,00^{c}
	B1 (4 Gy)	11,67	11,67	11,67^{a}
	B2 (6 Gy)	10,67	10,00	10,33^{a}
	B3 (8 Gy)	7,00	3,72	5,36^{ab}
	B4 (10 Gy)	6,75	3,50	5,13^{b}
	Average	7,22	6,58	
22	B0 (0 Gy)	0,00	4,00	2,00^{c}
	B1 (4 Gy)	11,67	11,75	11,71^{a}
	B2 (6 Gy)	10,83	10,00	10,42^{a}
	B3 (8 Gy)	7,17	3,88	5,53^{ab}
	B4 (10 Gy)	6,83	3,50	5,17^{b}
	Average	7,30	6,63	
23	B0 (0 Gy)	0,00	4,00	2,00^{c}
	B1 (4 Gy)	11,67	12,00	11,83^{a}
	B2 (6 Gy)	10,83	10,00	10,42^{a}
	B3 (8 Gy)	9,00	3,88	6,44^{ab}
	B4 (10 Gy)	7,00	3,50	5,25^{b}
	Average	7,70	6,68	
24	B0 (0 Gy)	0,00	4,00	2,00^{c}
	B1 (4 Gy)	12,00	12,08	12,04^{a}
	B2 (6 Gy)	11,00	10,15	10,58^{a}
	B3 (8 Gy)	9,00	3,88	6,44^{ab}
	B4 (10 Gy)	7,17	3,50	5,33^{b}
	Average	7,83	6,72	
25	B0 (0 Gy)	0,00	4,00	2,00^{c}
	B1 (4 Gy)	12,00	13,50	12,75^{a}
	B2 (6 Gy)	12,17	10,73	11,45^{a}
	B3 (8 Gy)	9,67	4,08	6,88^{ab}
	B4 (10 Gy)	7,17	3,50	5,3^{3b}
	Average	8,20	7,16	

Gamma ray radiation treatment with a dose of 4 Gy can provide optimal energy for cells to divide so that it affects the rate of cell division activity in sugar plant leaves. This statement is supported by Sari et al. (2020) [10], which states that mutations that occur due to gamma ray radiation can affect or change chemical reactions in plant cells which ultimately cause changes in gene structure to changes in plant chromosomes. Meanwhile, giving too high a dose can inhibit cell division which leads to cell death so that it affects plant growth and morphology.

Number of Leaves (Sheet)

Measurement of the number of leaves was conducted to determine the growth rate of sugar palm plants by manually counting the number of leaves on each plant sample. The data obtained was then processed and further tested as shown in Table 4.

Based on Table 4, the average number of best leaves is affected by the gamma ray dose factor. The 4 Gy dose is the best dose, which is also not significantly different from the 6 Gy dose based on the increase in the number of leaves each week. Based on research which had been conducted by Nurmayulis et al. (2021) [8], sugar palm plants at the age of 1 year produce an average number of leaves of 1. It supports that the 4 Gy dose is a suitable dose for the growth of the number of leaves in sugar palm plants since it is able to produce an average number of leaves of 2.75 at the age of 25 WAS. In contrast to plants with a dose of 4 Gy, plants treated with higher doses tend to have a lower average number of leaves. The results showing a significant difference in the number of leaves at several doses indicate that gamma ray radiation at certain doses can cause mutations in the cell division activity of meristem tissue in the leaf tips. It is in line with the statement of Zahra and Ariyanti (2025) [11] which states that leaves are where photosynthesis takes place, where this photosynthesis process affects the photosynthate that will be distributed to plant cells through the phloem tissue. The cells that receive the photosynthate will later divide at the tip of the stem and will produce new leaves. Thus, the more leaves produced, the more it will affect the results of photosynthesis.

Greenness of leaves (µ/cm2)

It was conducted in order to determine the growth rate of sugar palm plants by measuring the greenest part of the leaf using the SPAD (Soil Plant Analysis Development) measuring tool. The data obtained were then processed and further tested as shown in Table 5.

Based on table 5, leaf greenness is affected by the gamma ray dose factor with the best average at a dose of 6 Gy which is not significantly different from the doses of 4 Gy, 8 Gy, and 10 Gy. Therefore, it shows that this dose is able to provide mutations in the core genome in order to remodel the cell structure and metabolism in sugar palm plants; such as, the enlargement of the thylakoid membrane. It is in accordance with the research which had been conducted by Alfariatna et al. (2018) [1] regarding the physiological characteristics of shallots induced by gamma ray irradiation that the irradiation doses of 3 and 6 Gy showed higher chlorophyll content compared to the dose of 0 Gy. It is suspected that the chloroplasts in the cells have differentiated due to the import of proteins encoded by the core genome and cytoplasm involved in targeting proteins so that coordination of expression of core genes is needed by chloroplasts.

The significant difference between the four best doses and the treatment without dose shows that the amount of chlorophyll is affected by genetic factors due to gamma ray irradiation treatment by changing activity at the genome, chromosome, and DNA levels so that the physiological processes in genetically controlled cells become abnormal. In addition, in the control treatment, the amount of chlorophyll contained up to 24 WAS is less than optimal and tended to be lower compared to other doses. It is supported by research which had been conducted by Meliala et al. (2016)[6] that the amount of chlorophyll in rice leaves with gamma ray irradiation treatment increased compared to the control treatment.

In addition to being affected by genetic factors, the insignificant differences in the four doses can be affected by environmental factors, including the intensity of light received by each plant, temperature, and air humidity. It is in line with the statement of Zakiyah et al. (2018) [12] which stated that chlorophyll content is affected by external factors that are light intensity, temperature, and air humidity. Increasing the amount of chlorophyll will increase the ability

of plants to capture sunlight and will further accelerate the rate of photosynthesis. Furthermore, this statement is also reinforced by Butar (2005) [3] , that chlorophyll synthesis occurs in the hottest temperature range in the dry season. In addition, the entry of large light intensity and high temperatures will cause high evaporation.

Table 4. Average Increase in the Number of Leaves of Sugar Palm Plants from the Effect of Gamma Ray Dose Administration on Two Sugar Palm Varieties

Plant Age (WAS)	Gamma Ray Dose (B)	Varieties (V)		Average
		V1	V2	
18	B0 (0 Gy)	0,00	0,67	0,33^{bc}
	B1 (4 Gy)	1,33	1,83	1,58^{a}
	B2 (6 Gy)	1,67	1,50	1,25^{a}
	B3 (8 Gy)	0,67	1,00	0,83^{ab}
	B4 (10 Gy)	1,00	1,00	1,00^{ab}
	Average	0,93	1,20	
19	B0 (0 Gy)	0,00	0,67	0,33^{bc}
	B1 (4 Gy)	1,67	1,83	1,75^{a}
	B2 (6 Gy)	2,00	1,67	1,83^{a}
	B3 (8 Gy)	0,67	1,17	0,92^{ab}
	B4 (10 Gy)	1,00	1,00	1,00^{ab}
	Average	1,07	1,27	
20	B0 (0 Gy)	0,00	0,67	0,33^{bc}
	B1 (4 Gy)	2,00	2,17	2,08^{a}
	B2 (6 Gy)	2,00	2,00	2,00^{a}
	B3 (8 Gy)	1,00	1,17	1,08^{ab}
	B4 (10 Gy)	1,33	1,00	1,17^{ab}
	Average	1,27	1,40	
21	B0 (0 Gy)	0,00	0,67	0,33^{b}
	B1 (4 Gy)	2,00	2,00	2,00^{a}
	B2 (6 Gy)	2,00	2,00	2,00^{a}
	B3 (8 Gy)	1,67	1,17	1,42^{a}
	B4 (10 Gy)	1,33	1,00	1,17^{a}
	Average	1,40	1,37	
22	B0 (0 Gy)	0,00	0,67	0,33^{c}
	B1 (4 Gy)	2,33	2,50	2,42^{a}
	B2 (6 Gy)	2,00	2,00	2,00^{ab}
	B3 (8 Gy)	1,67	1,17	1,42^{ab}
	B4 (10 Gy)	1,33	1,00	1,17^{b}
	Average	1,47	1,47	
23	B0 (0 Gy)	0,00	1,00	0,50^{cd}
	B1 (4 Gy)	2,67	2,67	2,67^{a}
	B2 (6 Gy)	2,67	2,33	2,50^{a}
	B3 (8 Gy)	1,67	1,17	1,42^{ab}
	B4 (10 Gy)	1,50	1,00	1,25^{bc}
	Average	1,70	1,63	
24	B0 (0 Gy)	0,00	1,00	0,50^{cd}
	B1 (4 Gy)	2,67	2,67	2,67^{a}
	B2 (6 Gy)	2,67	2,50	2,58^{a}
	B3 (8 Gy)	1,67	1,17	1,42^{ab}
	B4 (10 Gy)	1,50	1,00	1,25^{bc}
	Average	1,70	1,67	
25	B0 (0 Gy)	0,00	1,00	0,50^{cd}
	B1 (4 Gy)	2,67	2,83	2,75^{a}
	B2 (6 Gy)	2,67	2,83	2,75^{a}
	B3 (8 Gy)	1,67	1,17	1,42^{ab}

	B4 (10 Gy)	2,00	1,00	1,50^{bc}
	Average	1,80	1,77	

Note: Numbers followed by the same letter in the same column indicate no significant difference in the further Duncan Multiple Range Test (DMRT) at 5%.

Table 5. Average increase in greenness of sugar palm leaves from the effect of administering gamma ray doses on two varieties sugar palm

Plant Age (WAS)	Gamma Ray Dose (B)	Varieties (V)		Average
		V1	V2	
		...(µ/cm^2)...		
20	B0 (0 Gy)	0,00	13,07	6,53^{bc}
	B1 (4 Gy)	42,23	34,73	38,48^{a}
	B2 (6 Gy)	49,27	36,60	42,93^{a}
	B3 (8 Gy)	26,93	24,23	25,58^{a}
	B4 (10 Gy)	15,70	20,53	18,12^{ab}
	Average	26,83	25,83	
24	B0 (0 Gy)	0,00	14,27	7,13^{b}
	B1 (4 Gy)	46,87	43,33	45,10^{a}
	B2 (6 Gy)	59,40	45,40	52,40^{a}
	B3 (8 Gy)	38,33	26,03	32,18^{a}
	B4 (10 Gy)	23,43	27,40	25,42^{a}
	Average	33,61	31,29	

Note: Numbers followed by the same letter in the same column indicate no significant difference in the further Duncan Multiple Range Test (DMRT) at 5%.

CONCLUSION

Based on the results of the study, various doses of gamma rays have a very significant effect on the growth rate of sugar palm plants observed through several parameters that are plant height, leaf width, number of leaves, and leaf greenness. The best dose of gamma rays is at a dose of 4 Gy for the parameters of plant height, leaf width, and number of leaves. Meanwhile, the best dose for the leaf greenness parameter is a dose of 6 Gy, which does not show any significant difference at doses of 4 Gy, 8 Gy, and 10 Gy. Therefore, further research is needed regarding DNA information on sugar palm plants that are mutated by gamma ray radiation at certain doses.

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