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Application of Gamma Radiation Doses on Two Varieties of Sugar Palm (*Arenga pinnata* MERR.) To Obtain The Best Growth Rate With Drought-Stressed Planting Media

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Abstract

Aren (*Arenga pinnata* Merr.) is a plant with high economic value. To obtain superior seeds, gamma radiation can be used, which has been proven to increase genetic variation and support optimal growth. This study aims to determine the effect of gamma radiation dosage and two varieties of aren on the optimal growth rate of aren (*Arenga pinnata* Merr.) using a drought stress growing medium. This study used a factorial Randomised Block Design (RBD). The first factor was the gamma radiation dose (B), consisting of 5 levels: 0 Gy, 4 Gy, 6 Gy, 8 Gy, and 10 Gy. The second factor was the palm variety (V), consisting of 2 levels: Parasi (V1) and local Lebak (V2). The results showed that the gamma ray dose of B2 or 6 Gy had the best effect on plant height, leaf width, number of leaves, and leaf greenness. The aren palm varieties (V) Parasi (V1) and local Lebak (V2) did not have a significant effect on plant height, leaf width, number of leaves, and leaf greenness. There was no interactive effect between gamma radiation dose treatment (B) and sugar palm variety (V) on plant height, leaf width, number of leaves, and leaf greenness.

***Keywords**: Aren* (*Arenga pinnata* Merr.), *gamma rays*, *palm varieties*

PENDAHULUAN

Aren palm (*Arenga pinnata* Merr.) is a plant of the Arecaceae family or palms whose potential has not been utilised, and 60% of the world's palm tree population is in Indonesia. According to Sakhidin *et al*. (2024), this plant is one of the plantation plants from the palm family. Its presence has excellent conservation value, high economic value, as well as important social value, and good prospects to be developed commercially due to its diverse uses. The aren palm plant can be found easily and grows naturally, making it a thriving wild plant in various forest types.

The production of aren palm plantation commodities in Banten province for three years showed a declining pattern. The production of aren palm plantation commodities experienced a significant decline from 2020 to 2022. Based on BPS data in 2020, production reached 4,035 tonnes, but experienced a sharp decline to 2,828 tonnes in 2021, and continued to decline to 1,569 tonnes in 2022. One of the factors resulting in the decline in palm production is the unavailability of superior seeds. Quality seedlings are those that are healthy, productive, and able to adapt well to the planting environment. Factors such as high-yielding, disease-free varieties, as well as genetic conditions and production environment greatly affect their quality. According to Anas *et al*. (2020), superior seeds are important for optimal agricultural yields. One method that can be used to improve the quality of seedlings in sugar palm plants is through the application of gamma radiation.

The use of gamma rays in agriculture can increase genetic diversity, produce superior varieties that are more productive, disease resistant, and adaptive. According to Ferdanti *et al*. (2023), the effects of gamma rays vary; the right dose promotes growth and accelerates harvest, but too high a dose can reduce its effectiveness.

In addition to the use of gamma radiation, one type of treatment to obtain superior mutants is drought stress selection which can be done by adding polyethylen glycol (PEG) to the planting media. PEG is a polymer that is often used as a solvent in the chemical and pharmaceutical industries (Pertiwi *et al*., 2021). PEG is also used as a plant selection agent against drought stress because it can reduce the water potential in the media (Zuyasna *et al*., 2016).

One method to obtain superior seedlings is through gamma radiation, such as in two palm varieties with drought-stressed planting media made from PEG solution. The use of radiation can produce new characters, but too high a dose risks creating undesirable traits. Therefore, choosing the right dose is important to achieve optimal results without disturbing the genetic stability of the plant.

RESEARCH METHODOLOGY

This research was conducted in February-May 2025 in the greenhouse of the experimental garden of the Department of Agroecotechnology, Faculty of Agriculture, Sultan Ageng Tirtayasa University. *Arenga pinnata* Merr. seeds were collected from Lebak Regency. The seeds were irradiated using IRPASENA irradiator with Co-60 source at the Isotope and Radiation Application Centre (PAIR), National Nuclear Energy Agency (BATAN), Pasar Jumat, South Jakarta. Tools and materials used included hoes, sacks, tarpaulins, 35 cm x 35 cm polybags, digital scales, gloves, white markers, knives, erlenmeyers, stirring rods, measuring cups, sprayers, SPAD502 Plus chlorophyll meter, upgraded Co60 Gamma Cell 220 irradiator, mobile phone camera, stationery, red spotlite paper, logbook, ruler, meter, palm seeds of Parasi and local Lebak varieties, polyethylen glycol (PEG 6000), distilled water, top soil, husk charcoal and cow dung fertiliser. This study used a Randomised Group Design (RAK) consisting of two factors, namely the first factor using gamma ray doses consisting of 5 levels, namely 0 gy, 4 gy, 6 gy, 8 gy, 10 gy treatments. While the second factor consisted of 2 levels, namely the Parasi variety of aren palm (V1) and the local Lebak variety of aren palm (V2) . Watering the plants using 250 ml of water per plant or polybag. The response design in this study was plant height (cm), number of leaves (Helai), leaf width (cm), and leaf greenness (µ/cm2) .

A. Preparation and Application of PEG 6000

The process of making PEG 6000 solution begins with preparing the tools and materials needed, namely measuring cups or containers, 1-litre bottles, Erlenmeyer flasks, distilled water, and PEG 6000. A total of 500 ml of distilled water was put into a measuring cup, then 50 grams of PEG 6000 was added to it. The mixture was then stirred using a stirring rod until well mixed. After that, the solution was transferred into an Erlenmeyer and shaken to make it homogeneous. The homogeneous solution was then put into a 1 litre bottle. This process was repeated until the bottle was completely filled with PEG 6000 solution with a concentration of 10% (with a ratio of 1 litre of distilled water and 100 grams of PEG 6000). After completion, the bottle was tightly closed to maintain the stability of the solution.

PEG 6000 solution with a concentration of 10% (a mixture of 1 litre of distilled water and 100 grams of PEG 6000) was given to the plants as much as 100 ml for each polybag. The application was carried out on plants aged 20 MST by pouring the solution around the plant, without hitting the plant directly.

B. Planting and Maintenance of Aren (*Arenga pinnata* Merr.) Plants

The irradiated aren palm seeds were then planted in the afternoon to reduce the risk of excessive evaporation due to high

temperatures in the morning. Planting was done in 35 × 35 cm polybags filled with planting media in the form of a mixture of surface soil, husk charcoal, and manure with a balanced composition (1:1:1), up to ¾ of the polybag. Plant maintenance included regular watering once a day in the morning or evening, adjusted to the field capacity of the planting medium. Weeds around the plants were cleaned manually so as not to interfere with the growth process of the palm seedlings.

C. Data Processing

Data obtained from observations were processed using Microsoft Excel for Windows, in testing the analysis of variance RAK 2 factors at the 5% level and further tests in this study with Duncan Multiple Range Test (DMRT) using Microsoft Excel for Windows

RESULTS AND DISCUSSION

The results of this study showed that the dose of gamma rays had a real effect. Based on the data obtained, parameters such as plant height, leaf width, number of leaves and greenness of the leaves indicated a significant effect on the dose of gamma rays Table 1.

Table 1. Results of Recapitulation of Variance Prints on the Application of Doses of Gamma Rays and Aren Varieties on the Growth of Aren Plants with Drought Stress Media

No	Observation Parameters	Plant Age (MST)	Treatment		Interaction (P*V)	KK (%)
			Gamma Ray Dose (B)	Aren Variety (V)		
1.	Plant height (cm)	18	**	tn	tn	10,26[a]
		19	**	tn	tn	10,54[a]
		20	**	tn	tn	10,55[a]
		21	**	tn	tn	10,55[a]
		22	**	tn	tn	10,51[a]
		23	**	tn	tn	10,75[a]
		24	**	tn	tn	10,66[a]
		25	**	tn	tn	10,66[a]
2.	Leaf width (cm)	18	**	tn	tn	6,92[a]
		19	*	tn	tn	6,75[a]
		20	**	tn	tn	6,79[a]
		21	*	tn	tn	7,47[a]
		22	**	tn	tn	7,21[a]
		23	**	tn	tn	7,45[a]
		24	**	tn	tn	7,75[a]
		25	**	tn	tn	7,75[a]
3.	Number of leaves (blade)	18	**	tn	tn	2,95[a]
		19	**	tn	tn	2,77[a]
		20	**	tn	tn	3,07[a]
		21	**	tn	tn	3,07[a]
		22	**	tn	tn	3,25[a]
		23	**	tn	tn	3,39[a]
		24	**	tn	tn	3,39[a]
		25	**	tn	tn	3,39[a]
4.	Leaf Greenness (µ/cm^2)	20	*	tn	tn	12,75[a]
		24	tn	tn	tn	11,86[a]

Keterangan:
- * : Significantly affected
- ** : Very significant effect
- tn : No significant effect
- KK : Coefficient of Variety
- MST : Week After Planting
- [a] : transformed $\sqrt{x} + 0{,}5$ by 3 times

The results of the recapitulation of variance showed that the dose of gamma rays had a very significant effect on plant height and the number of leaves. The real effect on leaf width only appeared at the age of 19 weeks after planting, while the other weeks showed a very real effect. The greenness of the leaves was significantly affected at the age of 20 weeks. Meanwhile, the varietal treatment and the interaction between gamma-ray dose did not have a significant effect on all parameters observed.

Plant Height (cm)

Measurement of plant height was carried out to determine the growth rate of sugar palm plants by measuring from the base of the lower stem to the tip of the highest plant using measuring instruments such as rulers and metres. The data obtained were then processed and tested further in Table 2.

Table 2. Average Results of Aren Plant Height Growth on the Application of Gamma Rays Doses and Aren Varieties with Drought Stress Media

Plant Age (MST)	Gamma Ray Dose (B)	Variety (V)		Average
		V1 (Parasi)	V2 (Banten local)	
		...(cm)...		
18	0 gy (B0)	11,33	22,17	16,75b
	4 gy (B1)	27,50	16,83	22,17a
	6 gy (B2)	26,17	19,13	22,65a
	8 gy (B3)	8,33	9,33	8,83b
	10 gy (B4)	15,42	8,50	11,96ab
	Average	17,75	15,19	
19	0 gy (B0)	11,33	22,17	16,75bc
	4 gy (B1)	27,67	17,42	22,54a
	6 gy (B2)	26,50	19,13	22,82a
	8 gy (B3)	8,50	9,83	9,17c
	10 gy (B4)	16,00	9,50	12,75ab
	Average	18,00	15,61	
20	0 gy (B0)	11,33	22,17	16,75bc
	4 gy (B1)	27,83	17,58	22,71a
	6 gy (B2)	26,75	19,25	23,00a
	8 gy (B3)	8,67	10,08	9,38c
	10 gy (B4)	16,25	10,00	13,13ab
	Average	18,17	15,82	
21	0 gy (B0)	11,50	22,17	16,83bc
	4 gy (B1)	28,00	17,92	22,96a
	6 gy (B2)	26,83	19,42	23,13a
	8 gy (B3)	8,67	10,42	9,54c
	10 gy (B4)	16,83	10,83	13,83ab
	Average	18,37	16,15	
22	0 gy (B0)	11,50	22,83	17,17bc
	4 gy (B1)	28,33	18,17	23,25a
	6 gy (B2)	27,58	22,42	25,00a
	8 gy (B3)	8,67	10,42	9,54c
	10 gy (B4)	18,58	11,50	15,04ab
	Average	18,93	17,07	
23	0 gy (B0)	11,50	23,83	17,67bc
	4 gy (B1)	28,67	18,22	23,44ab
	6 gy (B2)	27,75	22,42	25,08a
	8 gy (B3)	8,67	10,50	9,58c
	10 gy (B4)	19,75	11,67	15,71b
	Average	19,27	17,33	

24	0 gy (B0)	11,50	24,33	17,92bc
	4 gy (B1)	29,70	18,28	23,99ab
	6 gy (B2)	28,67	22,67	25,67a
	8 gy (B3)	8,67	10,50	9,58c
	10 gy (B4)	21,08	12,83	16,96b
	Average	19,92	17,72	
25	0 gy (B0)	11,5	24,33	17,92bc
	4 gy (B1)	30,67	18,50	24,58ab
	6 gy (B2)	28,67	23,00	25,83a
	8 gy (B3)	8,67	10,50	9,58c
	10 gy (B4)	22,08	14,33	18,21b
	Average	20,32	18,13	

Notes: The numbers followed by the same letter in the same row showed no significant difference in the DMRT 5% further test.

Based on Table 2. During the 8-week observation period, the best height growth of sugar palm plants was found in the treatment with a dose of 6 Gy gamma rays. On the contrary, the plants that were given a dose of 8 Gy showed lower development compared to the control (0 Gy). These results indicate that variations in gamma radiation doses are able to produce differences in growth response, reflecting the differential influence between exposed and non-exposed plants.

At the age of 25 weeks after planting, the sugar palm plants that received a dose of 6 Gy showed the best height growth, with an average of 25.83 cm. This is in line with the results of research conducted by Nurmayulis et al. (2021), local varieties of aren palm plants from Lebak showed an average height of 28.1 cm at the age of one year. This finding indicates that exposure to gamma radiation also plays a role in encouraging the increase in height growth of sugar palm plants. According to Mahmudi et al. (2023), gamma radiation at low doses (around 4-6 Gy) has the potential to stimulate vegetative growth of plants, such as height and number of leaves, without causing significant genetic damage. At this level, radiation is able to activate enzymes and accelerate metabolic processes, including cellular respiration and photosynthesis, which overall support increased plant growth.

Plant height growth after drought stress treatment did not show any slowdown or decrease in growth. This condition is thought to be related to the occurrence of mutations in plants due to exposure to gamma radiation, which increases the ability of plants to adapt and withstand drought conditions. According to Dewi and Wiendi (2023), gamma radiation can trigger genetic mutations that have the potential to strengthen plant resistance to drought conditions simulated with PEG. Radiation treatment at a certain level proved to have a significant effect on growth parameters, especially plant height, thus indicating that mutations resulting from gamma-ray exposure can help plants continue to grow optimally even though they are under stress conditions due to water shortage.

Leaf Width (cm)

Measurement of leaf width aims to evaluate the development of palm plant growth. Measurements were made on the widest leaf, starting from the right edge to the left edge using a ruler or metre. The measurement data were then analysed and used as the basis for further tests in Table 3.

Table 3. Average Results of Aren Leaf Width Increase on the Application of Gamma Rays Doses and Aren Varieties with Drought Stress Media

Plant Age (MST)	Gamma Ray Dose (B)	Variety (V)		Average
		V1 (Parasi)	V2 (Banten local)	
		...(cm)...		
18	0 gy (B0)	2,70	6,67	4,68ab
	4 gy (B1)	9,33	5,75	7,54a
	6 gy (B2)	7,92	5,50	6,71a
	8 gy (B3)	1,83	3,00	2,42b
	10 gy (B4)	4,25	1,60	2,93b
	Average	5,21	4,50	
19	0 gy (B0)	2,70	7,83	5,27ab
	4 gy (B1)	9,83	6,33	8,08a
	6 gy (B2)	9,67	6,50	8,08a
	8 gy (B3)	1,83	3,17	2,50b
	10 gy (B4)	4,92	2,50	3,71b
	Average	5,79	5,27	
20	0 gy (B0)	2,70	8,17	5,43bc
	4 gy (B1)	9,83	6,50	8,17a
	6 gy (B2)	10,50	6,67	8,58a
	8 gy (B3)	1,83	3,17	2,50c
	10 gy (B4)	5,42	2,67	4,04ab
	Average	6,06	5,44	
21	0 gy (B0)	3,93	9,67	6,80c
	4 gy (B1)	12,17	6,58	9,38ab
	6 gy (B2)	11,75	7,50	9,63a
	8 gy (B3)	1,83	3,17	2,50c
	10 gy (B4)	6,50	3,33	4,92bc
	Average	7,24	6,05	
22	0 gy (B0)	4,27	9,83	7,05b
	4 gy (B1)	14,17	6,67	10,42ab
	6 gy (B2)	12,83	7,92	11,04a
	8 gy (B3)	2,00	3,17	2,58c
	10 gy (B4)	5,75	4,33	5,04b
	Average	7,80	6,38	
23	0 gy (B0)	4,43	10,17	7,30c
	4 gy (B1)	14,50	7,33	10,92ab
	6 gy (B2)	13,00	8,17	11,29a
	8 gy (B3)	2,83	3,25	3,04d
	10 gy (B4)	8,92	4,83	6,88bc
	Average	8,74	6,75	
24	0 gy (B0)	4,43	10,17	7,30cd
	4 gy (B1)	14,67	7,50	11,08ab
	6 gy (B2)	12,25	8,33	11,54a
	8 gy (B3)	3,00	3,75	3,38d
	10 gy (B4)	9,00	5,00	7,00bc
	Average	8,67	6,95	
25	0 gy (B0)	4,43	10,33	7,38cd
	4 gy (B1)	14,67	8,00	11,33ab
	6 gy (B2)	13,67	9,92	11,79a
	8 gy (B3)	3,00	4,00	3,50d
	10 gy (B4)	9,25	5,00	7,13bc
	Average	9,00	7,45	

Notes: The numbers followed by the same letter in the same row showed no significant difference in the DMRT 5% further test.

Based on Table 3, the average during the observation period of 8 weeks, the treatment with a dose of 6 Gy gamma rays produced the best increase in leaf width on palm plants. On the contrary, the application of an 8 Gy dose showed lower leaf width growth compared to the treatment without radiation (0 Gy). At the age of 25 weeks after planting, the dose of 6 Gy produced the highest increase in leaf width of palm plants with an average of 11.79 cm. According to Nurmayulis et al. (2021), Lebak palm plants show an average leaf width of 6.8 cm at the age of one year. This growth is supported by the results of photosynthesis, which is processed through respiration into energy, which is then used by plant cells to increase size, thus encouraging a gradual increase in leaf width. This is in line with research by Hartati et al. (2022), radiation can trigger physiological responses in plants, such as an increase in growth hormones that stimulate cell and tissue development. Radiation also has the potential to increase photosynthetic efficiency by improving enzyme activity or light absorption, cell structure. These hormonal changes and increased photosynthesis promote faster vegetative growth, including an increase in leaf size or width in the early phase of growth.

Number of Leaves (Helai)

Measurement of the number of leaves was done by manually counting all the leaves that grew on each sample of palm plants, as an indicator to assess the level of vegetative growth of plants. The data obtained were then processed and tested further in Table 4.

Table 4. Average Results of Aren Leaf Number Increase on the Application of Gamma Rays Doses and Aren Varieties with Drought Stress Media

Plant Age (MST)	Gamma Ray Dose (B)	Variety (V)		Average
		V1 (Parasi)	V2 (Banten local)	
		...(cm)...		
18	0 gy (B0)	1,00	1,33	1,17b
	4 gy (B1)	1,67	1,17	1,42a
	6 gy (B2)	2,00	1,50	1,75a
	8 gy (B3)	0,33	0,83	0,58c
	10 gy (B4)	1,33	1,00	1,17b
	Average	1,27	1,17	
19	0 gy (B0)	1,00	1,67	1,33b
	4 gy (B1)	2,33	1,67	2,00a
	6 gy (B2)	2,17	1,67	1,92a
	8 gy (B3)	0,33	1,00	0,67c
	10 gy (B4)	1,83	1,33	1,58a
	Average	1,53	1,47	
20	0 gy (B0)	1,00	1,67	1,33b
	4 gy (B1)	2,67	1,67	2,17a
	6 gy (B2)	2,17	1,83	2,00a
	8 gy (B3)	0,67	1,00	0,83b
	10 gy (B4)	2,00	1,33	1,67a
	Average	1,70	1,50	
21	0 gy (B0)	1,00	1,67	1,33b
	4 gy (B1)	2,67	1,67	2,17a
	6 gy (B2)	2,17	2,00	2,08a
	8 gy (B3)	0,67	1,00	0,83b
	10 gy (B4)	2,00	1,33	1,67a
	Average	1,70	1,53	
22	0 gy (B0)	1,00	1,67	1,33b
	4 gy (B1)	2,67	1,67	2,17a

	6 gy (B2)	2,17	2,17	2,17a
	8 gy (B3)	0,67	1,00	0,83b
	10 gy (B4)	2,00	1,33	1,67a
	Average	1,70	1,57	
23	0 gy (B0)	1,00	1,67	1,33b
	4 gy (B1)	2,67	1,67	2,17a
	6 gy (B2)	2,83	2,17	2,33a
	8 gy (B3)	0,67	1,00	0,83b
	10 gy (B4)	2,00	1,33	1,67a
	Average	1,83	1,57	
24	0 gy (B0)	1,00	1,67	1,33b
	4 gy (B1)	2,67	1,67	2,17a
	6 gy (B2)	2,83	2,00	2,42a
	8 gy (B3)	0,67	1,00	0,83b
	10 gy (B4)	2,00	1,33	1,67a
	Average	1,83	1,53	
25	0 gy (B0)	1,00	2,00	1,50c
	4 gy (B1)	2,67	1,83	2,25b
	6 gy (B2)	3,17	2,00	2,58a
	8 gy (B3)	0,67	1,00	0,83c
	10 gy (B4)	2,00	1,33	1,67b
	Average	1,90	1,63	

Notes: The numbers followed by the same letter in the same row showed no significant difference in the DMRT 5% further test

Based on Table 4. the average during the observation period of 8 weeks, treatment with a dose of 6 Gy gamma rays produced the best increase in the number of leaves on the palm plants. In contrast, the application of a dose of 8 Gy showed lower leaf width growth compared to the treatment without radiation (0 Gy). At the age of 25 weeks after planting, the 6 Gy dose treatment produced the highest average increase in the number of leaves on the palm plants, which was 2.58 strands. According to Nurmayulis et al. (2021), at the age of one year, the average sugar palm plant produces one leaf. This number reflects the initial phase of growth, where plant energy is more focused on the formation of roots and stems. Based on research conducted by Mahmudi et al. (2024), the provision of gamma radiation at low doses of about 4-6 Gy can have a stimulating effect on early plant growth, especially on increasing the number of leaves. This effect occurs because radiation can trigger an increase in biochemical activities, such as enzyme activity and metabolic processes. As a result, photosynthesis and cellular respiration processes run more optimally, thus supporting vegetative growth without causing significant genetic damage.

The increase in the number of leaves still occurred despite the drought, indicating that water stress did not significantly inhibit leaf growth. This is an adaptive response due to gamma radiation treatment that helps maintain growth in unfavourable environmental conditions. According to the statement of Bashir and Setyawati (2025), plants that are still able to increase the number of leaves despite being in drought conditions are likely to experience genetic and epigenetic changes due to gamma-ray exposure. This adaptation allows plants to adjust to the stress of water shortage, so that they can still grow and develop normally.

Leaf Greenness (µ/cm2)

Leaf greenness assessment was conducted to measure the growth rate of palm plants by utilising the SPAD (Soil Plant Analysis Development) tool. This tool is attached to the greenest part of the leaf,

which is taken from the centre of the plant. This process uses a SPAD chlorophyll meter to obtain data on chlorophyll content as an indicator of growth. The data obtained were then processed and further tested in Table 5.

Table 5. Average Results of Aren Leaf Greenness Measurement on the Application of Gamma Ray Doses and Aren Varieties with Drought Stress Media

Umur Tanaman (MST)	Dosis Sinar Gamma (B)	Varietas (V)		Rata-rata
		V1 (Parasi)	V2 (Lokal Banten)	
		...(µ/cm^2)...		
20	0 gy (B0)	7,30	24,13	15,72b
	4 gy (B1)	39,40	17,37	28,38a
	6 gy (B2)	39,87	38,83	39,35a
	8 gy (B3)	12,17	12,80	12,48b
	10 gy (B4)	38,87	15,63	27,25a
	Average	27,52	21,75	
24	0 gy (B0)	9,13	27,47	18,30
	4 gy (B1)	45,23	17,27	31,25
	6 gy (B2)	45,93	40,73	43,33
	8 gy (B3)	11,33	24,13	17,73
	10 gy (B4)	36,20	18,93	27,57
	Average	29,56	25,71	

Notes: The numbers followed by the same letter in the same row showed no significant difference in the DMRT 5% further test

Based on Table 5, on average during the eight weeks of observation, the dose of gamma rays, 6 Gy, gave the best results on the level of greenness of the leaves of sugar palm plants. In contrast, the dose of 8 Gy produced a lower greenness value compared to plants that did not receive radiation treatment (0 Gy). Based on the results of research by Alfariatna *et al*. (2018), gamma radiation at a dose of 6 Gy is known to be able to increase chlorophyll levels in plant leaves. This increase in chlorophyll content makes the leaves look greener and fresher, which indicates an increase in the efficiency of the photosynthesis process. In general, gamma-ray irradiation in low to medium doses can trigger the activity of certain enzymes and improve the structure of plant cell tissues, especially chloroplasts, which play a direct role in chlorophyll formation. With increased photosynthetic efficiency, plants obtain more energy for growth. Although it can increase chlorophyll levels compared to other doses, the value of leaf greenness is still in the low category. This is in line with the research of Prabowo *et al*. (2018), the measurement of leaf greenness is divided into three categories: low, medium, and high. Leaves with greenness values below 50 units are categorised as low, values between 50 to 53 units are categorised as medium, and values above 53 units are categorised as high. At the age of 20 weeks after planting, sugar palm plants that were given a dose of 6 gy had an average leaf greenness of 39.35 units, so it was included in the low category

Measurement of leaf greenness at the age of 24 weeks after planting showed insignificant results. According to Aprilianto *et al*. (2023), a lack of water can reduce chlorophyll levels because the absorption of important nutrients such as nitrogen and magnesium is disrupted. Water plays an important role in dissolving and transporting nutrients throughout the plant, so an adequate water supply supports the absorption of nutrients for photosynthesis and chlorophyll production.

CONCLUSIONS

Based on the results of the study, various doses of gamma radiation have a significant effect on the growth of sugar

palm plants, as measured by plant height, leaf width, number of leaves, and leaf greenness. The dose of 6 Gy proved to be the most optimal in increasing the four parameters. Meanwhile, the variety of aren palm used did not have a significant impact on plant growth in the age range of 18 to 25 weeks after planting, and there was no significant interaction between radiation dose and variety of aren palm during the observation. Therefore, it is recommended to conduct a more in-depth follow-up study on the effects of the 6 Gy dose as well as the interaction with various palm varieties in order to obtain a more comprehensive understanding.

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