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The Effect of Gamma Ray Irradiation on Seed Viability and Plant Growth of Aceh's Local Rice (*Oryza sativa* L.)

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ABSTRACT

A study was carried to investigate the effect of gamma ray irradiation on seed viability of Aceh's local rice (*Oryza sativa* L.) genotypes on organically cultivated method. Seeds were irradiated with Radiator Gamma Chamber Co^60 at a dose of 250 Gy and 500 Gy. The results showed that the dose of gamma irradiation had a highly significant effect on germination capacity and seed growing unity. While, the maximum growth potential, growth velocity, and vigor index was not significantly affected by gamma ray irradiation dose. Gamma ray irradiation at a dose of 500 Gy resulted in more significant declining of seed viability compared with a dose of 250 Gy irradiation. Besides that, the dose irradiation had a highly significant effect on plant height, leaf number, and the number of tillers. The results also showed that the dose of gamma irradiation significantly interacted with the rice varieties to germination capacity, growth velocity, plant height, and number of leaves. Whereas, the maximum growth potential, vigor index, seed growing unity, and the number of tillers showed no significant interaction between varieties with the dose of gamma irradiation. Increasing doses of irradiation resulted in insignificant reduction of the germination capacity in varieties of *Cantek Manis*, *Rom Mokot*, and *Sanbei*. Conversely, varieties *Sigupai* and *Ramos Mirah*'s germination capacity decreased significantly with the increasing dose gamma ray irradiation. Meanwhile, increasing doses of gamma irradiation on the genotypes *Cantek Manis*, *Rom Mokot*, and *Sanbei* caused enhancing the growth velocity of seed. Inversely, varieties of *Sigupai* and *Ramos Mirah*'s growth velocity decreased significantly with increasing doses of gamma ray irradiation.

KEYWORDS: rice, local genotype, viability, vigor, gamma ray, irradiation

INTRODUCTION

Local varieties of rice germplasm is a potential source of genes that control important traits in plants. Aceh province, located at the northwestern tip of the Sumatera island of Indonesia, has a high genetic variation of the local rice [7]. Some of the advantages of local rice are the maintenance is minimal; requires a low inputs, has a good adaptation; belongs a tasty favored by consumers, confers high levels of tolerance to stresses, and high yield potential. However, local varieties have also some disadvantages, such as long-lifespan and some of them are low productivity [10]. Hence, improvement of local rice with mutation techniques is one way to accelerate a breeding program. Targets for improvement of rice are to produce new varieties with superior traits in accordance with the respective typology rice region, such as dryland, saline soil, and low fertility soil [8].

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Gamma ray irradiation is one mutation techniques are currently widely used in rice breeding programs [3,15,16]. Some researchers suggest that gamma ray irradiation causes a faster seed germination. This is caused by the fact that short-wavelength photons gamma rays are stronger than photons of visible light so that it has a stronger effect on the surface of plant cells. This causes damage to the seed coat layer which enables faster germination [2].

However, gamma ray irradiation dose required varies depending on the genotypes of rice. Low doses of gamma rays showed no significantly effect on seed germination. Some research indicates that a dose of 300 Gy caused a decrease in the percentage of germination [5]. Harding *et al.* [9] suggested that gamma ray irradiation dose increase above 300 Gy cause severe physiological damage the seedling height, the percentage of survival in the field and production. Irradiation is done on food crops especially rice, is intended to reduce the negative character and enhance the positive character. Mutation induction with radiation is the most frequently used method to develop direct mutant varieties. Thus, the technique of gamma ray irradiation on Aceh's local rice varieties were used in this study to generate mutants with properties desired, such as has a lot of productive tillers, able to adapt to the environmental stress, and has a rapid flowering period.

Methodology:

This research was conducted from March to August, 2015 in the Laboratory of Seed Science and Technology and Experimental Farm, Faculty of Agriculture, University of Syiah Kuala. Selected seeds were irradiated in Center for Application Isotop and Radiation, National Nuclear Energy Agency of Indonesia. The study was designed as a Split Plot Design in Block Randomized pattern with three replications. Varieties were arranged as main plots (*Sigupai*, *Cantek Manis*, *Rom Mokot*, *Ramos Mirah*, and *Sanbei*) and gamma-ray irradiation dose as subplots (without irradiation, 250 Gy, 500 Gy). Data were tested using analysis ANOVA and Duncan's New Multiple Range Test (DNMRT) level of 5%.

The selected seeds put in Radiator Gamma Chamber Model 4000A Co^60 for irradiation at a dose of 250 Gy for 36"15' and 500 Gy for 72"30'. The application of Gamma rays was carried out in the Laboratory of BATAN, Jakarta. Then, the rice seeds germinated in an incubator for three days with a temperature of 30°C. Germinated seeds were sowed and maintained in a seedling tray for 14 days. The seedlings were planted in a pot containing a mixture of Entisol soil and organic fertilizer (Petroganik 100 g/pot or 10 tons/ha). Irrigation was done without flooding, but by watering the plants everyday to field capacity. The rice plants were maintained by weeding and controlling pests and diseases intensively.

Observation of seed viability was carried out on the maximum growth potential, germination capacity, growth velocity, vigor index, and simultaneity of growth. The maximum growth potential is the percentage of all seeds that live or showed symptoms of life, both normal and produce sprouts abnormal. Germination test is done by taking a random 100 grains of seed from each sample package for germination. The germination capacity was observed on the 10^{th} day after seed imbibition. Observations on the vegetative phase of plant performance conducted on plant height, number of leaves, and the number of tillers at 15, 30, 60, and 90 days after planting (DAP).

Results:

Effect of rice genotypes on seed viability:

Table 1 indicated that the genotypes had significant effect on all variables of seed viability, including maximum growth potential, germination capacity, growth velocity, vigor index, and simultaneity of growth. Genotype of *Cantek Manis* was the best genotype with the highest seed viability (maximum growth potential, germination capacity, growth velocity, and simultaneity of growth). While, better vigor index was found on the genotypes of *Cantek Manis*, *Rom Mokot*, and *Sanbei*.

Table 1: Average the maximum growth potential (MGP), germination capacity (GC), growth velocity (GV), vigor index (VI), and simultaneity of grow (SG) from different genotypes of Aceh's local rice.

Varieties	MGP (%)	GC (%)	GV (%/etmal)	VI(%)	SG (%)
Sigupai	86.22 a	72.00 ab	14.75 a	36.00 a	55.11 a
Cantek Manis	99.55 b	94.22 c	20.71 b	58.66 b	75.11 c
Rom Mokot	90.22 a	87.11 ab	18.48 ab	52.88 b	71.11 abc
Ramos Mirah	94.22 ab	76.44 ab	16.08 a	41.77 b	58.22 ab
Sanbei	95.11 ab	89.33 ab	18.22 ab	56,44 b	74.66 bc

Description: Figures followed by the same letter in the same column is no significant effect on the level of 5% (Test DNMRT-0.05)

Effect of rice genotypes on the plant growth:

Table 2 shows that genotypes resulted a significant effect on plant height at 15, 30, 60, and 90 days after planting. While, the number of leaves were significantly different at 15, 30, 60 days after planting. Genotypes also resulted a very significant effect on the number of tillers of plants at the age of 30 and 60 days after planting. However, at the age of 90 days after planting, the genotypes had no real effect on the number of leaves and number of tillers. The results showed that genotypes *Rom Mokot*, *Cantek Manis*, and *Sanbei* at age 15 days after planting were higher plant height from others, respectively 24.45 cm, 24.16 cm. Meanwhile, at the age of 30 days after planting, the *Rom Mokot*, *Sigupai*, *Cantek Manis*, and *Sanbei* were the genotypes with a higher average of plant height respectively was 56.82 cm, 54.66 cm, 51.7 cm, 51.06 cm, and 15.06 cm. This observation recovered that *Sigupai* was the highest plant height at age both 60 and 90 days after planting.

Table 2: Average plant height, leaf number, and number of tillers of Aceh's local rice genotypes at age 15, 30, 60, and 90 Days After Planting (HST)

Plant Performances	Genotypes	Age of plant (days after plating, DAP)			
		15 DAP	30 DAP	60 DAP	90 DAP
Plant height (cm)	*Sigupai*	13,80 a	54,66 b	78,74 c	96,68 c
	Cantek Manis	24,16 b	51,75 b	65,94 bc	83,35 bc
	Rom Mokot	24,45 b	56,82 b	72,88 bc	94,91 bc
	Ramos Mirah	15,06 a	36,38 a	46,89 a	51,98 a
	Sanbei	24,14 b	51,06 ab	60,70 ab	80,82 b
Leaf number	*Sigupai*	2,22 a	11,05 a	16,83 a	20,25 a
	Cantek Manis	3,19 b	25,01 b	36,83 b	34,05 b
	Rom Mokot	3,39 b	21,17 b	30,41 ab	29,53 ab
	Ramos Mirah	2,89 b	20,77 b	36,10 b	37,54 b
	Sanbei	3,32 b	23,11 b	40,17 b	34,11 b
Number of tillers	*Sigupai*	*	3,45 a	4,99 a	4,37 a
	Cantek Manis	*	7,55 b	10,28 a	8,59 b
	Rom Mokot	*	6,12 b	7,74 a	7,24 b
	Ramos Mirah	*	6,32 b	10,19 a	10,06 b
	Sanbei	*	6,87 b	10,11 a	8,29 b

Description: Figures followed by the same letter in the same column no significant effect on the level of 5% (Test DNMRT 0.05). * The plant did not perform tiller.

Effect of gamma ray irradiation on seed viability:

Table 3 showed that the irradiation dose given very significant effect on germination capacity and simultaneity grow of the seeds. While, the maximum growth potential, growth velocity, and vigor index had no real effect on the dosage of gamma ray irradiation. The average germination capacity of the seed was best seen in the control treatment amounted to 90.40%. While, the average simultaneity of grow was highest at 250 Gy irradiation treatment that is equal to 72.26%. Meanwhile, the control treatment had an average growth potential maximum, growth velocity, and index of vigor were the higher compared with other treatments, but a statistically had no significant effect on growth potential maximum, growth velocity, and vigor index of the Aceh's local rice genotypes.

It was found that increasing doses of irradiation resulted in insignificant reduction of the germination capacity in varieties of *Cantek Manis*, *Rom Mokot*, and *Sanbei*. Conversely, varieties *Sigupai* and *Ramos Mirah*'s germination capacity decreased significantly with the increasing dose gamma ray irradiation. However, increasing doses of gamma irradiation on the genotypes *Cantek Manis*, *Rom Mokot*, and *Sanbei* caused enhancing the growth velocity of seed. Inversely, varieties of *Sigupai* and *Ramos Mirah*'s growth velocity decreased significantly with increasing doses of the irradiation.

Table 3: Average the maximum growth potential (MGP), germination capacity (GC), growth velocity (GV), vigor index (VI), and simultaneity of grow (SG) on different dose gamma ray irradiation.

Gamma ray irradiation	MGP(%)	GC (%)	GV(%/etmal)	IV (%)	SG (%)
Control	94.93a	90.4b	18.35a	52.80a	70.40a
Irradiation 250 Gy	92.00a	86.93ab	18.13a	51.20a	72.26a
Irradiation 500 Gy	92.26a	74.13a	16.44a	43.46a	57.86a

Description: Figures followed by the same letter in the same column no significant effect on the level of 5% (Test DNMRT0,05)

Effect of gamma ray irradiation on plant growth:

Table 4 shows that a significant influence of different dose irradiation on plant height at 15, 30, 60, and 90 days after planting, the number of leaves at 15 and 30 days after planting, as well as the number of seedlings at 30 days after planting. However, the use of irradiation dose no real effect on the number of leaves and number of tillers at the age of 60 and 90 days after planting. The average plant highest at age 15, 30, 60, and 90 days after planting found in the control treatment with consecutive high is 26.56 cm, 55.55 cm, 72.60 cm, and 88.70 cm. The irradiation treatment of 250 Gy had an average number of leaves and highest at age 15, 30, 60, and 90 days after planting. However, gamma ray irradiation treatment had no significant effect on the number of leaves at the age of 60 and 90 days after planting.

Dose of 250 Gy irradiation also resulted the highest number of tillers at the age of 30, 60, and 90 days after planting. However, gamma ray irradiation treatment did not effect significantly on the growing number of plant tiller at the age of 60 and 90 days after planting. It was found that the plant height tested at doses of 250 and 500 Gy irradiation were shorter than the control treatment.

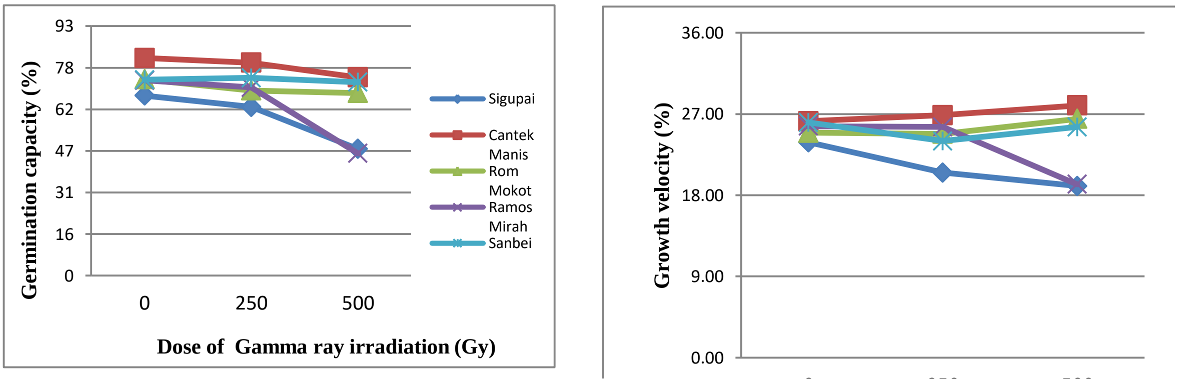
Table 4: Average plant height, leaf number, number of tillers at age 15, 30, 60, and 90 days after planting due to the effect of gamma ray irradiation

Plant Performance	Gamma Ray Irradiation	Plant age (days after planting, DAP)			
		15 DAP	30 DAP	60 DAP	90 DAP
Plant Height (cm)	Control	26,56 c	55,55 a	72,60 a	88,82 a
	Irradiation 250 Gy	22,50 b	51,80 a	66,70 a	83,53 a
	Irradiation 500 Gy	11,88 a	43,04 a	55,79 a	72,56 a
Leaf number	Control	2,96 ab	21,67 a	29,77 a	28,99 a
	Irradiation 250 Gy	3,24 b	22,02 a	34,80 a	33,21 a
	Irradiation 500 Gy	2,78 a	16,96 a	31,62 a	31,08 a
Number of tillers	Control	*	6,32 a	8,09 a	7,20 a
	Irradiation 250 Gy	*	6,74 a	9,11 a	8,09 a
	Irradiation 500 Gy	*	5,12 a	8,78 a	7,83 a

Description: Figures followed by the same letter in the same column no significant effect on the level of 5% (Test DNMRT 0.05). * The plant did not perform tiller

Interaction between genotypes and dose irradiation:

Figure 1 and 2 showed that there was an interaction among the rice genotypes with the dose of gamma ray irradiation on the growth velocity, plant height and number of leaves at 15 and 30 days after planting. Significant interaction also occurred between rice genotypes with gamma ray irradiation dose at the variable of germination capacity. While, the growing potential maximum, vigor index, simultaneity grow, plant height and number of leaves and number of tillers at the age of 60 and 90 days after planting showed no significant interaction between the genotypes of rice with irradiation dose of gamma rays used.



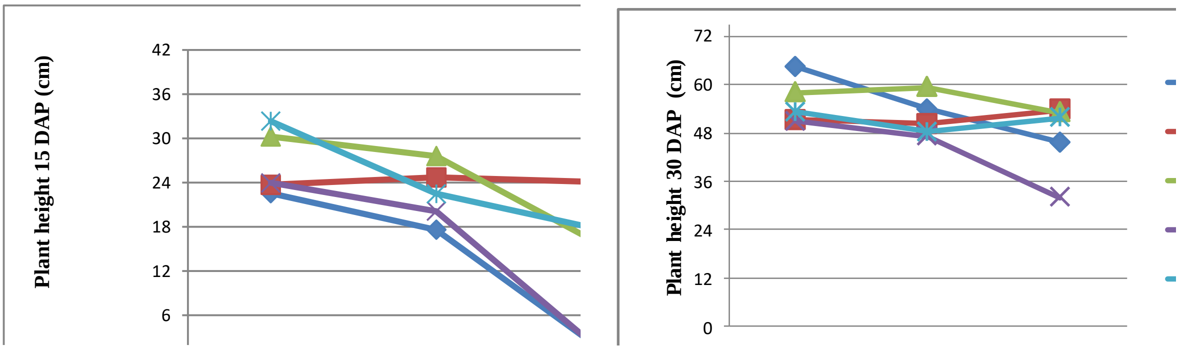
(a) (b)

Fig. 1: Interaction among the rice genotypes with the dose of gamma ray irradiation on the germination capacity and growth velocity of seeds after irradiated with 250 Gy and 500 Gy.

Figure 1 showed that increasing doses of irradiation on the genotypes *Cantek Manis*, *Rom Mokot*, and *Sanbei* resulted in insignificant reduction of the germination of seeds. Conversely, genotypes *Sigupai* and *Ramos Mirah* decreased germination significantly with increasing dose gamma ray irradiation. Meanwhile, increasing doses of gamma irradiation on the genotypes *Cantek Manis*, *Rom Mokot*, and *Sanbei* increased the growth velocity of seeds.

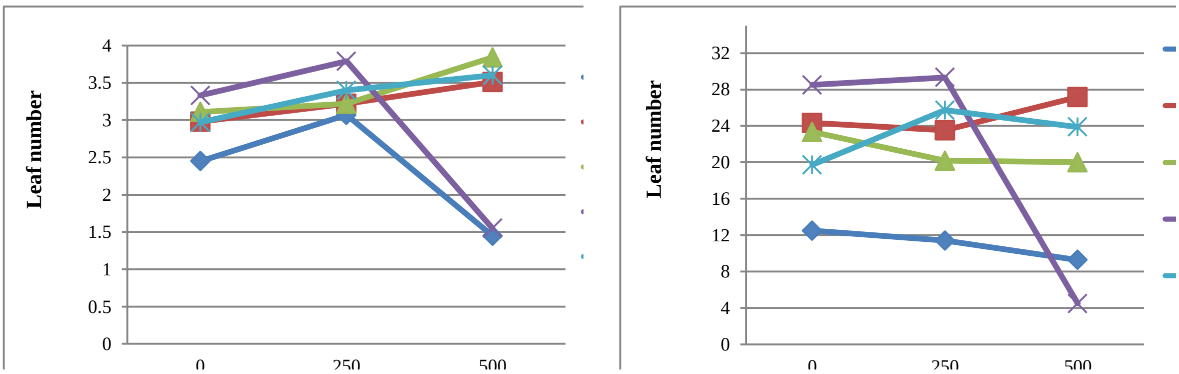
Figure 2 shows that the higher the dose of irradiation decreased the plant height both at plant age of 15 and 30 days after panting. This research found that the plant height of genotypes of *Sigupai*, *Rom Mokot*, *Ramos Mirah*, and *Sanbei* reduced significantly due to increasing doses of gamma ray irradiation. Conversely, increasing doses of gamma ray irradiation had no significant effect on plant height of *Cantek Manis* genotype. Meanwhile, at the age of 30 days after planting, increasing irradiation dose given at genotypes of *Sigupai*, *Rom Mokot*, and *Ramos Mirah* resulted in the shorter plant height. Conversely, increasing doses of gamma irradiation on the genotypes *Cantek Manis* and *Sanbei* seen no effect on plant height.

Figure 3 showed the interactions between genotypes with gamma ray irradiation dose occurred the number of leaves of plants at age 15 days after planting. Genotypes *Sigupai* and *Ramos Mirah* experienced a significant reduction in the number of leaves when the irradiation dose increased. In contrast, the number of leaves of the genotypes *Cantek Sweet*, *Rom Mokot*, and *Sanbei* increased with the rise in gamma ray irradiation dose. At the age of 30 days after planting, increased gamma-ray irradiation dose caused the number of leaves of the plant genotypes *Mirah Ramos* significantly reduced. It was also found on the genotypes *Sigupai*, *Rom Mokot*, and *Sanbei* experiencing a reduction in the number of leaves due to increasing doses of gamma ray irradiation. Conversely, increasing doses of gamma ray irradiation increased the number of leaves on the genotype *Cantek Manis*.



(a) (b)

Fig. 2: Interaction among the rice genotypes with the dose of gamma ray irradiation on plant height at age 15 and 30 days after planting of plant produced from seeds after irradiated with 250 Gy and 500 Gy



(a) (b)

Fig. 3: Interaction among the rice genotypes with the dose of gamma ray irradiation on leaf number at age 15 and 30 days after planting of plant produced from seeds after irradiated with 250 Gy and 500 Gy

Discussions:

This research discovered that gamma ray irradiation had a highly significant effect on seed viability and plant growth of Aceh's local rice. Gamma ray irradiation at a dose of 500 Gy resulted in more significant declining of seed viability compared with a dose of 250 Gy. The results also showed that the dose of gamma irradiation significantly interacted with the rice genotypes to germination capacity, growth velocity, plant height, and number of leaves. Whereas, the maximum growth potential, vigor index, seed growing unity. Increasing doses of irradiation resulted in insignificant reduction of the germination capacity especially in genotypes of *Cantek Manis*, *Rom Mokot*, and *Sanbei*.

According Delouche and Baskin [6] the process of seed germination is influenced by internal factors such as the level of maturity of seeds, seed size, dormancy and germination inhibitors. These negative effects thought to be caused by damage to or alteration of chromosomal arrangement of genes and disruption of physiological processes of seed by gamma ray irradiation. The damage changed by the emergence of free radicals that can damage the phospholipids and proteins of the cell membrane so that the seeds induced decline and decreased seed viability. Exposed seed to irradiation caused some changes that characterized by declining quality of seed physiology that effected an overall change in the seed, whether physical, physiological and biochemical [13]. Gamma ray irradiation treatment at a dose of 500 Gy showed caused significantly decreased seed viability compared with irradiation dose of 250 Gy. The results of the study of Islam [12] and Ali *et. al*. [1] also showed that the irradiation dose of 500 Gy enhanced negative effect on rice seed germination capacity.

Giving higher dose irradiation effected on high genetic damage, causing the physiological activity of rice plants disrupted and cause death in plants that are not tolerant. However, Hegazi and Hamideldin [11] found gamma-ray irradiation dose of 500 Gy is less effective than the lower dose. This happens according to low irradiation dose to inhibit the synthesis of auxin whereas higher irradiation doses can impair the activity of auxin directly. Figure 4 shows that increasing doses of gamma ray irradiation reduced significantly the number of tillers on genotype of *Ramos Mirah*. It is also found on the genotypes *Sigupai*, *Rom Mokot*, and *Sanbei* which has decreased the number of tillers due to increasing doses of gamma ray irradiation. Conversely, increasing doses of gamma ray irradiation increased the number of leaves on the genotype of *Cantek Manis*.

It was discovered that plant height was reduced when the irradiation dose increases and this reduction is directly proportional with increasing dose of irradiation [14]. In contrast, the number of leaves and number of tillers at control treatment was fewer than plants produced from seeds irradiated with the dose of 250 and 500 Gy.

Conclusion:

The dose of gamma irradiation had a highly significant effect on germination capacity and seed growing unity. While, the maximum growth potential, growth velocity, and vigor index was not significantly affected by gamma ray irradiation dose. Gamma ray irradiation at a dose of 500 Gy resulted in more significant declining of seed viability compared with a dose of 250 Gy irradiation.

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