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Improvement of Rice Phenotype of M4 Sigupai Irradiated by Gamma Ray

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Abstract:
Background: *Improvement of local rice phenotype characters for variety assembly, from generation to generation is the main thing in plant breeding. The purpose of this study was to determine the improvement of the characters of several M4 Sigupai genotypes resulting from gamma ray irradiation.*
(10)
Materials and Methods: *The design used in this study was a non-factorial randomized block design (RBD) with 3 replications. The treatments studied were the genotypes (G) consisting of 12 levels, namely the parent Sigupai (G0), the Mustajab National Mutant (G1) and 10 M4 Sigupai (G2-G11) with 3 replications to obtain 36 treatment units.*
Results: *The M4 Sigupai genotype on phenotypic characters showed that the number of tillers in the SM4-3 and SM4-1 genotypes was not significantly different from the Mustajab variety, the fastest heading date was in the SM4-3 and SM4-5 genotypes with heading date of 68 DAS, the fastest harvest date was the SM4-3 genotype, namely 103 DAS, panicle length SM4-10, the highest number of panicles SM4-3 was not significantly different from Mustajab. High yield potential was SM4-5 genotype and the best harvest index was SM4-2 genotype. Plant height, weight of pithy grain and weight of 1000 grains showed no significant effect.*
Conclusion: *Based on the results, it can be concluded that the SM4-3 genotype had improved the character of the number of tillers, heading date, harvest date and number of panicles better than non-irradiated Sigupai varieties.*

Key Word: *Local Rice, Genotype, Agronomic*

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I. Introduction

Rice (*Oryza sativa* L.) is a staple food crop that is widely cultivated and consumed by the world community, which is about 40% of the world's population or 3.2 billion people consume rice [1]. The Central Statistics Agency (2020) reports that rice production in Indonesia in the form of milled dry unhulled rice (GKG) in 2020 is 55.16 million tons and in 2019 is 54.60 million tons, which has decreased production from 2018, namely 59.20 million tons. It is said that rice production with population growth in Indonesia is inversely proportional to 2018, namely 265.09 million, 2019 with 268.07 million and 2020, 270.20 million. This shows that the level of consumption of the Indonesian population continues to increase every year [2].

The decline in rice production is due to global warming, changes in rainfall, floods, drought, the occurrence of strong winds and rising sea levels [3]. High salinity in the soil can also reduce productivity, limit land stability and affect biomass and crop yields [4]. The decline in crop yields in most regions of the world is partly due to drought [5].

One technique to increase rice production is by using the gamma ray irradiation mutation technique [6]. Gamma ray irradiation mutation technique is able to induce mutation processes rapidly in genetic material or DNA changes and can increase the diversity of plant varieties. These new varieties have beneficial properties such as having resistance to climate change and being able to increase higher yields [7]. Environmental adaptive, has high economic value and is part of the conservation of germplasm [8].

The Sigupai variety is Aceh's local rice which has a delicious, fluffier and aromatic taste of rice but has a long harvest life of 6 months [9]. Aceh's local varieties have proven their advantages such as high yield potential [10], tolerant of acid soils [9] and resistance to drought and resistance to high temperatures [11].

Mutations resulting from gamma ray irradiation can improve the character of the stems to be short and have an early age (Sasikala and Kalaiyarasi, 2010). Improve agronomic properties in rice plants [12].

Gamma ray irradiation in creating new varieties has specific selection stages in M1 to M9 generations, M1 gets superior strains, M2 selects superior mutants according to the target breeders, M3 selects superior mutants based on agronomic performance and yield components, M4 selects the best mutants from 50-100 genotypes, M5 selects the best mutants from 25-50 genotypes, M6 performs a preliminary yield test, M7 performs an advanced yield test, M8-M9 performs a multi-location test [13].

The research results of Warman et al 2015 show that gamma ray irradiation at a dose of 200 Gy can improve the agronomic properties of local West Sumatra rice from high-stem to short-stem. Furthermore, it was explained by Yunita et al. 2020 that at this dose the M3 mutants of Ciherang and Inpari 13 rice had high resistance to salinity [14]. Character improvements that occur in M4 Mentik Susu irradiated with 100 Gy and 200 Gy gamma rays show lower stems, shorter flowering and harvesting lives and higher productivity than nonirradiated Mentik Susu rice [15].

The improvement of characters in the assembly of varieties is very necessary to know the development from generation to generation, in order to show characters that are much better than the previous generation and is an effective way of selecting mutant genotypes to become superior varieties [16]. which are capable of producing high production and adaptive to the environment. Sigupai variety has a unique advantage with low amylose content (fluffier) and aromatic compared to other local rice but has some bad agronomic characteristics such as long harvest life, high which is not ideal so it easily collapses (Litbang, 2017). The results of previous research on the M1-M3 Sugupai M1 derivative had a plant height of 122 cm, a harvest date of 97 DAS, and had a potential yield of 7.8 tonnes ha1, at M2 had a plant height of 114 cm, a harvest date of 95 DAS, and yield potential 8.2 tonnes ha1, in M3 has a plant height of 105-122 cm and a harvest date of 77 DAS. So that in some M4 Supai genotypes, it is necessary to conduct research on the improvement of phenotypic characters to be able to select and produce better mutant genotypes and is also an important requirement in assembling a local variety into a superior national variety.

II. Material And Methods

This research was conducted from May 2020 to December 2020. Location of planting the M4 Sigupai genotype on the land of the Aceh Rice Research Institute (ARRI) East Darussalam Sector, Banda Aceh.

Study Design: This study used a non-factorial randomized block design (RBD) with 3 replications. The treatments studied were genotypes consisting of 12 levels, namely Sigupai non irradiation (G0), Mustajab National mutant (West Java mutation) (G1) and 10 M4 Sigupai (G2-G11) with 3 repetitions in order to obtain 36 treatment units. Sampling is by taking 5 clumps in each genotype which enter the fastest growing phase.

Study Location: Location of planting the M4 Sigupai genotype on the land of the Aceh Rice Research Institute (ARRI) East Darussalam Sector, Banda Aceh. Its geographic location is at 50 57'1.63 "LU-950 37 ',1.09’’BT with an altitude of 13 masl (Mobile Topography, 2019).

Study Duration: May 2020 to December 2020.

Procedure methodology

The planting area has an area of 168 m2 (8 x 21 m) and has 3 replications, for replications has 12 treatment genotypes. The plot area is 2.90 m2 (1.45 x 2 m). The spacing is 15 x 30 cm, the plant holes are 13 x 5 = 65 planting holes, the need for seeds is 65 x 3 is 195 seeds/plot, screen house and irrigation with brackish water with salinity of 6-8 mosh.

The tools used in this study were hand-tractors, analytical scales, seedblowers, blackout meters, plastic clips, scissors, plastic ropes, label paper and writing instruments. The materials used in this study were M4 Sigupai seeds, Sigupai non-irradiated seeds (Control) and West Java mutation seeds (comparison).

The basic fertilizers used are NPK Fertilizer (15: 15: 15%) and 125 kg N required per plot of 242.875 g, Mg with a per plot requirement of 242.875 g, PETROGANIK (organic fertilizer) (2 tonnes ha-1) and required 580 g per plot. The first fertilizer to be used is ZA (21% N) and 63 kg N required with a per plot requirement of 86,942 g. The second fertilization used ZA (21% N) and 31.25 kg N needed with the needs per plot of 43,152 g and KCl (50 kg ha -1) which was needed and the requirement per plot was 14.5 g.

Statistical analysis

Data was analyzed using SPSS version 25 (SPSS Inc., Chicago, IL). The data obtained were analyzed by using the F test and if it shows the effect, then it is followed by the Honestly Significant Difference (BNJ) test at the 5% (0.05) level.

III. Result

Phenotype

The results showed that the M4 sigupai Genotype had a very significant effect on the number of tillers, heading date, harvest date but had no significant effect on plant height. The average phenotypic characters in the M4 Sigupai genotype are shown in Table 1.

Table 1. Average phenotypic characters in the M4 Sigupai

Galur	Plant Height (cm)	Number of Panicle	Heading Date (DAS)	Harvest Date (DAS)
Sigupai	150	10.0 ^{ab}	110 ^{c}	145 ^{c}
Mustajab	136	11.67 ^{b}	82 ^{b}	117 ^{b}
SM4-1	135	9.67 ^{ab}	70 ^{a}	104 ^{a}
SM4-2	137	8.33 ^{a}	69 ^{a}	105 ^{a}
SM4-3	137	10.0 ^{ab}	68 ^{a}	103 ^{a}
SM4-4	139	9.0 ^{a}	71 ^{a}	106 ^{a}
SM4-5	136	8.67 ^{a}	68 ^{a}	105 ^{a}
SM4-6	134	7.67 ^{a}	70 ^{a}	104 ^{a}
SM4-7	135	8.67 ^{a}	69 ^{a}	105 ^{a}
SM4-8	134	9.33 ^{ab}	70 ^{a}	105 ^{a}
SM4-9	135	8.67 ^{a}	71 ^{a}	105 ^{a}
SM4-10	137	9.33 ^{ab}	72 ^{a}	106 ^{a}
BNJ 0.05	-	1.06	1.73	2.13

Description: The numbers followed by the same letter in the same column are not significantly different at the 5% probability level (LSD 0.05)

Table 1 shows the lower plant height tended to be found in the SM4-6 and SM4-8, namely 134 cm and the highest plant height was found in the Sugapai variety with a plant height of 150 cm. The better number of tillers was found in the SM4-3, Sigupai, SM4-1, SM4-10 and SM4-8 which were not significantly different from Mustajab varieties but significantly different from the SM4-6, SM4-2, SM4-5, SM4-7, SM4-9, SM4-4. The best heading date was shown in the SM4-3 and SM4-5 which were not significantly different from the SM4-2, SM4-7, SM4-6, SM4-8, SM4- 1, SM4-4, SM4-9, SM4-10 and Mustajab varieties. The heading date of the M4 Sigupai genotypes was significantly different from the Sigupai variety. Harvest date of the M4 Sigupai genotype has a fast harvesting age ranging from 103 to 105. Better harvesting date were found in SM4-3, which was 103 days which was not significantly different from the SM4-6, SM4-1, SM4- 2, SM4- 9, SM4-5, SM4-7, SM4-8, SM4-4, SM4-10 and Mustajab varieties but significantly different from Sigupai varieties

Yield componen

Results showed that the M4 Sigupai genotype had a very significant effect on panicle length, yield potential and harvest index and had a significant effect on the number of panicles but had no significant effect on pithy grain weight and 1000 grain weight. The average production characters are shown in Table 2.

Table 2. Average yield componen the M4 Sigupai

Galur	Panicle length (cm)	Productive panicles per plant	Weight of pithy grain (g)	1,000-grain weight (g)	Grain Yield (ton ha^{-1})	Harvest Indeks (g)
Sigupai	22.7 ^{a}	9.6 ^{ab}	21.8	24.3	2.7 ^{a}	0.37 ^{a}
Mustajab	29.3 ^{c}	10.1 ^{b}	21.5	20.0	3.9 ^{ab}	0.51 ^{a}
SM4-1	27.3 ^{bc}	9.1 ^{ab}	21.9	20.0	5.2 ^{abc}	0.85 ^{bc}
SM4-2	26.7 ^{b}	7.6 ^{a}	19.4	21.0	5.1 ^{abc}	0.97 ^{c}
SM4-3	26.7 ^{b}	9.1 ^{ab}	21.1	21.0	6.0 ^{bc}	0.91 ^{c}
SM4-4	26.3 ^{b}	7.9 ^{ab}	21.2	23.0	5.6 ^{bc}	0.86 ^{bc}
SM4-5	27.0 ^{bc}	8.5 ^{ab}	23.5	20.3	6.5 ^{c}	0.83 ^{bc}
SM4-6	26.0 ^{b}	8.0 ^{ab}	17.5	21.3	5.1 ^{abc}	0.87 ^{bc}
SM4-7	26.7 ^{b}	8.8 ^{ab}	22.4	21.0	5.6 ^{bc}	0.82 ^{bc}

SM4-8	27.0 bc	8.8 ab	21.9	20.3	5.9 bc	0.74 abc
SM4-9	27.3 bc	8.9 ab	22.9	21.0	6.0 bc	0.85 bc
SM4-10	27.3 bc	8.0 ab	20.3	22.7	5.0 abc	0.89 c
BNJ 0.05	1.02	0.97	-	-	1.04	0.15

Description: The numbers followed by the same letter in the same column are not significantly different at the 5% probability level (LSD 0.05)

Table 2 shows the better panicle length were the SM4-10, SM4-9, SM4-1, SM4-8, SM4-5 genotypes which were not significantly different from Mustajab varieties but significantly different from Sigupai varieties, SM4-6, SM4-4, SM4-2, SM4-3 and SM4-7. Better panicle numbers were found in the SM4-3, SM4-1, SM4-9, SM4-8, SM4-7, SM4-5, SM4-10, SM4-6, SM4-4 which were not significantly different from Mustajab varieties and Sigupai variety but significantly different from the SM4-2. The weight of pithy grain has no significant effect, but it can be seen that the average value that tends to be better is found in genotypes that have a pithy grain weight above 21 g, namely SM4-5, SM4-9 and SM4-7 and genotypes that have an average weight of grain grains tend to be higher. low is SM4-6.

The weights of 1000 grains tended to be better in sequence, namely the Sigupai varieties, SM4-4, SM4-10, SM4-6, SM4-9, SM4-7, SM4-3, SM4-2, SM4-8, SM4-5 , SM4-1 and Mustajab varieties.

The weight of 1000 grains of grain have no significant effect. The best potential yield was shown in the SM4-5 which were not significantly different from the SM4-9, SM4-3, SM4-8, SM4-4, SM4-7, SM4-1, SM4-6, SM4-2, SM4-10 but significantly different from the comparison varieties, namely Mustajab and Sigupai varieties. The yield index for the M4 strains of Sigupai had a very significant effect. The better average harvest index values were found in the SM4-2, SM4-3, SM4-10 which were not significantly different from SM4-6, SM4-4, SM4-9, SM4-1, SM4-5, SM4- 7, SM4-8, but significantly different from the Sigupai variety and Mustajab Variety.

IV. Discussion

Plant height in the M4 Sigupai genotype has no significant effect and has a high plant height category. The height of rice plants has a short rice category 130 [17]. The M4 mutants of local Philippine rice resulting from gamma ray irradiation did not show a good effect on plant height characters compared to M1 to M3 [18].

The number of tillers in Mutant M4 Sigupai was not significantly different from the control, this was because the irradiated plants occurred randomly and had not yet stabilized [15]. The number of tillers in the Sigupai M4 was medium and small. In accordance with the category of tillers in rice plants, namely (25) very many categories [19].

The heading date of the M4 Sigupai genotype is 68-71 DAT and includes a fast flowering age. Furthermore, it was explained that the fast or long flowering period is controlled by the action of the dominant additive gene, so that the more dominant the gene is in an individual, the flowering age is correlated in determining the fast or slow harvest time [20].

Mutant rice resulting from gamma ray irradiation has the ability to accelerate flowering age, concurrent flowering, seed filling period so as to produce a faster harvest date [21], Kasim et al., 2020). Changes in the arrangement of chromosomes and DNA due to gamma ray irradiation can stimulate mutations that affect the metabolism of plant growth. One of them affects the metabolism of the photosynthetic process which is able to accelerate the supply of nutrients needed to produce seeds so as to shorten the harvest life [22].

The length of the M4 Sigupai rice panicles was not significantly different from the Mustajab variety. Mutant rice has panicles that are longer than non-mutant panicles and panicle length is correlated with the number of grains per panicle, the longer the panicles, the greater the number of grains per panicle is expected and is an important character in the selection of mutant rice [23]. [24] added that many of the grain grains are accommodated by long panicles. Local rice mutants do not only have long panicles, of course, they also contain grains that are medium in type [25]. Panicle length in mutant rice is caused by the encoding of panicle length genes in F box protein and can interact with protein so that it is involved in modulation of cytokinin levels in plant tissue, namely panicle architecture [26]. The number of panicles in M4 non-Basmati Aromatic mutant rice has a positive effect because the dominance of additive genes in stressing the number of panicles and the number of panicles affects the number of grains and grain weight in its formation [27]. Additive genes in mutant rice are also able to influence the phenotypic properties of panicles, namely related to the number of grains per panicle, panicle weight and weight of 1000 grains of grain [28].

The weight of rice grain in M4 Sigupai have a weight that tends to be higher in the SM4-5 genotype, namely 23.5 g. Variation in rice grain weight in the generation of mutant rice genotypes resulting from gamma ray irradiation because it has not reached a homogeneous generation, namely on M8. Irradiation provides growth randomization in mutant rice so that it doesn't look too good [29].

The weight of 1000 grain of M4 Sigupai is the low weight of 1000 grains. As stated by [30], the weight of 1000 grains weighing <25 g is in the low category. Yield components in the form of plant height, number of productive tillers, 1000 grain weight, and harvest age have a positive correlation with the yield of harvested grain weight. Meanwhile, flowering age is negatively correlated with the weight of harvested grain or yields and the unpredictable season causes the weight of 1000 grains to be lower than the potential yield [31]

In line with [32], M4 Sigupai rice has a much higher yield potential than the comparison varieties. The mutant rice FukuhibikiH8, FukuhibikiH6, YamadawaraH3 resulting from gamma ray irradiation affects the yield potential which is much higher this is due to the editing of the rice genome thereby increasing the yield. An important requirement in determining the success of plant breeding consists of several interrelated components, namely plant height, seed per clump, panicle per clump, panicle length, number of filled and unfilled grains, 1000 grain weight and total grain weight [33]. Environmental factors also influence the development of yield components to produce high yield potential [34].

The M4 Sigupai's rice yield index had a higher harvest index than the comparison varieties. The high harvest index in rice plants is caused by the early flowering of rice, which ranges from 75-85 days (Sujinah et al., 2020). Mutant rice resulting from gamma ray irradiation can increase nutrition in rice so that it can improve agronomic properties, increase total amino acids, antioxidants, chlorophyll and also grain quality properties [35]. The harvest index is the effectiveness of biomass to provide harvestable yields, which is the ratio between the yields of economic value compared to the total weight of biomass. The harvest index in plants is an indication of the effectiveness of photosynthate translocation to the harvested portion in the form of grain.

V. Conclusion

SM4-3 genotype has been able to improve the character of the number of tillers, heading date, harvest date and number of panicles better than non-irradiated Sigupai varieties. The SM4-3 genotype had approached mustajab and had much greater yeild potential than the sigupai and musajab varieties.

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