The short-stemmed selection of M4 generation of Mentik Susu rice mutants as irradiation result with 200 gray gamma ray

The short-stemmed selection of M4 generation of Mentik Susu rice mutants as irradiation result with 200 gray gamma ray

M F Saweho[1], E Purwanto[2] and A Yunus[2]

[1]Student of Agrotechnology, Agriculture Faculty, University of Sebelas Maret, Surakarta 57126, Central Java, Indonesia
[2]Lecturer of Agrotechnology, Agriculture Faculty, University of Sebelas Maret, Surakarta 57126, Central Java, Indonesia

E-mail: yunus.uns7@yahoo.com

Abstract. This study observed the performance of mutated M4 generation of "mentik susu" rice irradiated with 200 Gy gamma ray and select the high productivity short-stemmed ones. The research was conducted in Karangpung Village, Kismoyoso, Ngemplak, Boyolali Regency. In total, 39 individual M3 200 Gy gamma ray irradiated "mentik susu" rice and non-irradiated "mentik susu" rice as control were planted. The observation was analyzed descriptively and used t-test to know the difference with the control. There were differences between irradiated and non-irradiated rice on plant height, harvest time, number of productive tillers, weight of 100 grains, and grain yield per plant. There were 25 selected mutated M4 generation "mentik susu". Those strains were M-MS2-G15T3- 2 (5),(19),and (27), M-MS2-G15T3- 4 (7) and (28), M-MS2-G15T3- 5 (21), M-MS2-G15T3- 7 (18) and (28), M-MS2-G15T3- 8 (5), M- MS2-G15T4-24 (10), M-MS2-G13T20- 12 (17) and (27), M-MS2-G18T7- 4 (4),(5),(9), and (24), M- MS2- G18T7- 6 (19) and (24), M- MS2- G18T7- 7 (11) and (24), M-MS2- G18T7- 10 (5), M- MS2- G18T7- 11 (24), and M- MS2- G17T7- 15 (2) and (10) which were irradiated, and have short-stemmed characteristic and higher production compared to the control.

1. Introduction

Mentik susu rice is local variety from Magelang, Central Java, Indonesia. Most farmer are not interested to plant this variety of rice because it requires a long period to grow, high stem, and low yield, which is in contrast to the national rice varieties that have a short harvest time and high productivity [1].

The technology can be used to increase the productivity of major food like rice is by mutation breeding techniques [2]. Mutation breeding is deemed better to repair one or several properties just by not changing most of its original properties. Mutations can be done with a wide range, such as using gamma radiation. Desirable mutation can cause the diversity of the properties that will be selected, thus better character is selected but still maintain plants characters.

Genetic mutations using radiation beam is an alternative method to obtain new sources of diversity [3]. Based on the description above, this study aimed to result mentik susu rice M4 generation with gamma-ray irradiation 200 Gy. Furthermore, short stemmed mutant was selected. Gamma radiation beam irradiation at a dose of 200 Gy was expected to generate short-stemmed plants, short-lived and high productivity in order to obtain new varieties.

2. Methods

The research was conducted in the paddy field Karangpung Village, Kismoyoso, Ngemplak, Boyolali. The study used 39 seeds of M4 mentik susu rice as a result from gamma ray irradiation 200 Gy (selection results M3) and mentik susu rice without radiation l (control). The research was designed as a simple design of experimental design. The experiment was done by planting 39 individual M3 200 Gy gamma ray irradiated mentik susu rice and non-irradiated mentik susu rice.

3. Result and discussion

3.1. Plant height

Plant height often observed as an indicator to measure the environmental impact of growth or treatment applied. Gamma ray irradiation at 200 Gy resulted high influence to mentik susu M4 generation (Table 1). This was in accordance with previous study where radiation with physical mutagens reduced plant height mutant [4].

Table 1. Plant height mentik susu rice with gamma 200 Gy ray irradiation

Strain M4	Shortest (cm)	Longest (cm)	Range	Average (cm)
M-MS2-G15T3-2	75	87	75- 87	81.20 ± 6.20 *
M-MS2-G15T3-4	76	89	76- 89	82.50 ± 6.69 *
M-MS2-G15T3-5	83	88	83- 88	85.80 ± 2.57 *
M-MS2-G15T3-7	82	92	82- 92	86.70 ± 5.17 *
M-MS2-G15T3-8	85	94	85- 94	89.70 ± 4.79 *
M-MS2-G15T4-24	85	91	85- 91	88.00 ± 3.40 *
M-MS2-G16T5-7	86	92	86- 92	89.00 ± 3.09 *
M-MS2-G5T7-12	89	93	89- 93	91.20 ± 1.81 *
M-MS2-G5T7-16	89	94	89- 94	91.30 ± 2.67 *
M-MS2-G13T20-29	84	88	84- 88	86.00 ± 2.36 *
M-MS2-G18T7-4	76	88	76- 88	82.00 ± 6.34 *
M-MS2-G18T7-6	81	89	81- 89	84.70 ± 3.80 *
M-MS2-G18T7-7	83	90	83- 90	86.40 ± 3.86 *
M-MS2-G17T7-10	86	98	86- 98	87.60 ± 2.01 *
M-MS2-G17T7-11	84	87	84- 87	85.90 ± 1.45 *
M-MS2-G17T7-13	81	86	81- 86	83.20 ± 2.66 *
M-MS2-G17T7-15	78	83	78- 83	80.30 ± 2.26 *
CONTROL	127	138	127-138	132.80 ± 5.47

Numbers followed by sign (*) significantly different from the control based on the results of t test with $\alpha = 0.05$

The highest plant was obtained by the control plants (without radiation) with a height of 132.80 cm high-range 127-138 cm. Lowest plant height 200 Gy radiation results there in strain M4M-MS2 with a high-G15T3-2 which has a 75 cm height (range 75-87 cm) with an average of 81.20 cm. Previous research showed differences in plant height than the previous generation (M3) of about 13 cm [5]. Decreased in plant height was due to chromosomal damage as a result of irradiation processes [6].

T test results showed that 200 Gy of gamma irradiation reduced plant height, indicated crop diversity due to gene mutations of irradiation.

3.2. Harvest time

Harvesting or physiological maturity age is used to determine right harvest time. Characteristics of physiological maturity is when 80-85% of grains and leaves are yellowing, the stalks are bent under bear the increased grain weight, and when grain pressed it will feel hard and unbiased [7]. Provision of 200 Gy irradiation affected to harvesting time. Irradiation with 200 Gy accelerated maturity age (Table 2).

Table 2. Harvest time mentik susu rice as a result of gamma 200 Gy ray irradiation

Strain M4	Harvest Time (days)
M-MS2-G15T3-2	88
M-MS2-G15T3-4	88
M-MS2-G15T3-5	88
M-MS2-G15T3-7	88
M-MS2-G15T3-8	88
M-MS2-G15T4-24	91
M-MS2-G16T5-7	91
M-MS2-G5T7- 12	89
M-MS2-G5T7- 16	89
M-MS2-G13T20-12	89
M-MS2-G13T20-29	88
M-MS2-G18T7- 4	88
M-MS2-G18T7- 6	88
M-MS2-G18T7- 7	90
M-MS2-G17T7- 10	90
M-MS2-G17T7- 11	90
M-MS2-G17T7- 13	90
M-MS2-G17T7- 15	90
CONTROL	135

Control (mentik susu rice without irradiation)

Age of harvest of mentik susu rice resulted from 200 Gy was 88-91 days. Meanwhile, the control plants have a lifespan of 135 days harvest. Gamma ray irradiation at a dose of 0.2 kGy can produce strains of shorter lifespan [8]. Mutations in the chromosome as a result of administration of gamma rays can lead to a shorter-lived of rice [9].

Harvesting time of mentik susu rice M4 generation of gamma ray irradiation results 200 Gy indicated the homogeneity and significantly different from the control, which similar to previous studies [5]. Mentik susuM3 200 Gy irradiated has the earliest harvest age 88 days. This suggests that gamma ray irradiation affects to the time of harvesting. A dose of 0.2 kGy induced mutation proved to be done to get the plant with early harvesting time [10].

3.3. Number of productive tillers

A productive tiller produces panicles. The greater number of productive tillers per hill, the greater number of panicles per hill. A 200 Gy of gamma ray can increase the number of tillers mentik susu rice [11].

The control mentik susu rice M4 has a number of productive tillers range between 11-17 with an average of 13.80. Productive tillers highest result 200 Gy of gamma irradiation contained in strain M-MS2-G13T20-29 as many as 33 straws that have a range of 20 to 33 straws with an average of 26.50. T test results showed administration of 200 Gy of gamma irradiation significantly different from control. Gamma-ray irradiation plants produce productive tillers number that is higher than the parent [12].

Table 3. The number of productive tillers mentik susu rice as results of gamma 200 Gy ray irradiation

Strain M4	Lowest	Supreme	Range	Average
M-MS2-G15T3-2	9	27	9-27	18.00 ± 9.20 *
M-MS2-G15T3-4	18	27	18-27	22.40 ± 4.60 *
M-MS2-G15T3-5	20	30	20-30	24.90 ± 5.17 *
M-MS2-G15T3-7	21	28	21-28	24.30 ± 3.30 *
M-MS2-G15T3-8	18	28	18-28	22.80 ± 5.18 *
M-MS2-G15T4-24	17	30	17-30	23.40 ± 6.59 *
M-MS2-G16T5-7	20	30	20-30	24.90 ± 4.61 *
M-MS2-G5T7- 16	19	31	19-31	25.10 ± 6.12 *
M-MS2-G13T20-12	18	30	18-30	24.20 ± 5.85 *
M-MS2-G13T20-29	20	33	20-33	26.50 ± 6.65 *
M-MS2-G18T7- 4	20	32	20-32	25.70 ± 6.02 *
M-MS2-G18T7- 6	22	32	22-32	27.00 ± 5.46 *
M-MS2-G18T7- 7	21	28	21-28	24.50 ± 3.54 *
M-MS2-G17T7- 10	22	32	22-32	26.70 ± 5.06 *
M-MS2-G17T7- 11	22	27	22-27	24.50 ± 2.59 *
M-MS2-G17T7- 13	13	25	13-25	19.00 ± 5.72 *
M-MS2-G17T7- 15	15	30	15-30	22.60 ± 7.17 *
CONTROL	11	17	11-17	13.80 ± 3.12

Numbers followed by sign (*) significantly different from the control based on the results of t test with $\alpha = 0.05$

3.4 Panicle length

M4 panicle length in this research showed a decrease rather than M3 (Table 4). The mutant plants were irradiated with gamma radiation changed the components of reproduction such as the number of panicle and panicle length [13].

Table 4. Panicle length mentik susu rice as result of gamma 200 Gy ray irradiation

Strain M4	Shortest (cm)	Longest (cm)	Range	Mean Flat
M-MS2-G15T3-2	22.85	25.03	22,85- 25.03	23.94 ± 1.09 *
M-MS2-G15T3-4	21.91	24.41	21,91- 24.41	23.16 ± 1.25 *
M-MS2-G15T3-5	22.53	24.27	22,53- 24,27	23.40 ± 0.87 *
M-MS2-G15T3-7	22.44	24.44	22,44- 24.44	23.44 ± 1.00 *
M-MS2-G15T3-8	22.70	24.36	22,70- 24.36	23.53 ± 0.83 *
M-MS2-G15T4-24	22.31	24.05	22,31- 24.05	23.18 ± 0.87 *
M-MS2-G16T5-7	21.63	24,50	21,63- 24,50	23.06 ± 1.43 *
M-MS2-G5T7- 12	23.27	25.42	23,27- 25.42	24.34 ± 1.08 *
M-MS2-G5T7- 16	22.98	25.05	22,98- 25.05	24.02 ± 1.04 *
M-MS2-G13T20-12	22.60	24.65	22,60- 24.65	23.62 ± 1.03 *
M-MS2-G13T20-29	22.78	24.29	22,78- 24.29	23.54 ± 0.76 *
M-MS2-G18T7- 4	22.64	23.98	22,64- 23.98	23.31 ± 0.67 *
M-MS2-G18T7- 6	22.54	23.94	22,54- 23.94	23.24 ± 0.70 *
M-MS2-G18T7- 7	22.43	24.07	22,43- 24.07	23.25 ± 0.82 *
M-MS2-G17T7- 10	22.46	24.56	22,46- 24.56	23.51 ± 1.05 *
M-MS2-G17T7- 11	22.41	24.20	24,41- 24,20	23.30 ± 0.90 *
M-MS2-G17T7- 13	21.58	23.52	21,58- 23,52	22.55 ± 0.97 *
M-MS2-G17T7- 15	21.92	24.20	21,92- 24,20	23.06 ± 1.14 *
CONTROL	25.68	31.45	25,68- 31.45	28.68 ± 2.88

Numbers followed by sign (*) significantly different from the control based on the results of t test with $\alpha = 0.05$

The longest panicle was showed by control plants which a length of 31.45 cm. The length of the longest panicle rice Mentik susu 200 Gy radiation that results in strainM-MS2-G5T7- 12 with a 25.42

cm panicle length and the average length of panicle 24.34 cm. T test results showed administration of 200 Gy of gamma irradiation significantly different from the control plants. Results showed Mentik susu rice panicle length M4of controls is longer than the crops of 200 Gy of gamma ray irradiation. This is in accordance with previous finding that radiation did not always produce a better crop [14].

The average length of the longest panicle M3 is 26.83 cm [5]. The decreased in the average length of panicle occurred on the M4 as much as 2.49 cm. This was due to rice blast disease that attacks the research field. Blast disease caused by the fungus *Pyricularia oryzae* can attack the leaves and a book on the pommel panicle and disturb the growth [15].

3.5 Index of panicle

Panicle heaviness index is the ratio between the number of grains per panicle with panicle length [16]. Plant control in this research have panicles heaviness index higher than 200 Gy irradiation (Table 5). Panicle heaviness index indicates the number density of grain or seed that grows in a panicle.

Table 5. Index of Panicle mentik susu rice result of gamma 200 Gy ray irradiation

Strain M4	Average Number of Grains per Panicle (grain)	Average Length of Panicle (cm)	Index Luxuriance Tassel
M-MS2-G15T3-2	112.96	23.94	4.70 *
M-MS2-G15T3-4	108.14	23.16	4.66 *
M-MS2-G15T3-5	108.22	23.40	5.48
M-MS2-G15T3-7	105.46	23.44	4.49 *
M-MS2-G15T3-8	110.04	23.53	4.68 *
M-MS2-G15T4-24	94.50	23.18	4.07 *
M-MS2-G16T5-7	102.76	23.06	4.44 *
M-MS2-G5T7- 12	114.66	24.34	4.69 *
M-MS2-G5T7- 16	114.58	24.02	4.77 *
M-MS2-G13T20-12	106.34	23.62	4.49 *
M-MS2-G13T20-29	105.08	23.54	4.47 *
M-MS2-G18T7- 4	105.30	23.31	4.51 *
M-MS2-G18T7- 6	102.18	23,24	4.39 *
M-MS2-G18T7- 7	105.54	23.25	4.53 *
M-MS2-G17T7- 10	104.96	23.51	4.46 *
M-MS2-G17T7- 11	101.12	23,30	4.33 *
M-MS2-G17T7- 13	102.16	22.55	4.51 *
M-MS2-G17T7- 15	111.62	23.06	4.83 *
CONTROL	181.17	28.68	6.35

Numbers followed by sign (*) significantly different from the control based on the results of t test with $\alpha = 0.05$

The results showed that the control plants had an average index of 6.35 with the longest panicles 26.68 cm and number of grains per panicle 181.17. Mentik susu rice 200 Gy irradiated in lines M-MS2-G15T3-5 has the highest index of heaviness panicles 5.48, which 23.40 cm panicle length and number of grains 108.22. These results indicate that the average flash of rice panicle rice control was denser than mentik susu rice M4 generation results 200 Gy of gamma radiation. In line with the average panicle length control plants were higher than crops of 200 Gy irradiation. Panicle potential heaviness index is determined by the amount of total grain and panicle length [17].

3.6 Weight 100 grains

Mentik susu rice results 200 Gy of gamma irradiation has a weight of 100 grains were heavier than control. The 100-grain weight is the number of filled grain biomass contained in the grain. The amount of grain that contains (pithy) indicates the more biomass contained in it.

Table 6. Weight of 100 grains of mentik susu rice as result of gamma 200 Gy ray irradiation

Strain M4	Lowest (G)	Supreme (G)	Range	Average
M-MS2-G15T3-2	2.21	2,68	2.21- 2.68	2.44 ± 0.24 *
M-MS2-G15T3-4	2.23	2.57	2.23 - 2.57	2.40 ± 0.17 *
M-MS2-G15T3-5	2.11	2.58	2.11- 2.58	2.34 ± 0.24 *
M-MS2-G15T3-7	2,14	2.41	2.14 - 2.41	2.28 ± 0.13 *
M-MS2-G15T3-8	2.10	2,81	2.10 - 2.81	2.45 ± 0.35 *
M-MS2-G15T4-24	2.03	2,54	2.03 - 2.54	2.29 ± 0.25 *
M-MS2-G16T5-7	2.35	2.70	2.35 - 2.70	2.52 ± 0.17 *
M-MS2-G5T7- 12	2.34	2,68	2.34 - 2.68	2.51 ± 0.17 *
M-MS2-G5T7- 16	2.30	2,68	2.30 - 2.68	2.49 ± 0.19 *
M-MS2-G13T20-12	2.18	2,78	2.18 - 2.78	2.48 ± 0.30 *
M-MS2-G13T20-29	2.31	2,59	2.31 - 2.59	2.45 ± 0.14 *
M-MS2-G18T7- 4	2.41	2.65	2.41 - 2.65	2.53 ± 0.12 *
M-MS2-G18T7- 6	2.26	2,69	2.26 - 2.69	2.48 ± 0.21 *
M-MS2-G18T7- 7	2.20	2.52	2.20 - 2.52	2.36 ± 0.16 *
M-MS2-G17T7- 10	2.31	2,63	2.31 - 2.63	2.47 ± 0.16 *
M-MS2-G17T7- 11	2.15	2.40	2.15 - 2.40	2.27 ± 0.12 *
M-MS2-G17T7- 13	2.16	2.55	2.16 - 2.55	2.35 ± 0.20 *
M-MS2-G17T7- 15	2.29	2.55	2.29 - 2.55	2.42 ± 0.13 *
CONTROL	2.06	2.33	2.06 - 2.33	2.19 ± 0.13

Numbers followed by sign (*) significantly different from the control based on the results of t test with $\alpha = 0.05$

Based on Table 6 control plants had an average weight of 100 grains of 2.19 g with a range 2.06-2.33 g. The weight of an average of 100 grains in mentik susu rice results 200 Gy of gamma irradiation highest obtained by the strain M-MS2-G18T7-4 is 2.53 g with a weight range 2.41- 2.65 g. Gamma ray irradiation mutant plants which have an average weight of 100 seeds was significantly higher compared with controls (plant origin) [18]. Based on t test results of 200 Gy of gamma ray irradiation managed to make the weight of 100 grains to be higher than the control plants.

3.7 Yield per plant

Mentik susu rice M4 200 Gy irradiation results show higher productivity grains than control. Production of gamma-ray irradiation mutation IR 64 in Vietnam getting strains have greater yield of 15-20% of the parents [19]. Seed yield per plant is determined by the number of productive tillers, panicle length, number of grains per panicle and weight of 100 seeds. When these properties show a high yield, most result of seeds per plant are also high [20].

Based on Table 7, strains M-MS2-G15T3-2 has the yield per plant by weight of 92.01 g with a range of 41.00 to 92.01 g. Control plant has an average weight of 24.76 g with a range of grain yield 36.51 g – 24.76 g. T test results showed administration of 200 Gy of gamma irradiation significantly different from the control plants. Based on the results of the T test gamma ray irradiation of 200 Gy make crop grain yield higher than the control plants. Seed yield per plant is the correlation of the various components of the results [21]. Components of the crop is the number of panicles, number of grains per panicle and weight of 100 seeds. The high one component will affect the results of the high seed yield per clump.

In a previous study, M3 200 Gy irradiation results in strain-coded M-MS2-15-3 which have seed yield per plant of 91.00 g [5]. Changes that occur in grain yield per plant M4 amounting 1.01 g. M4 in strain M-MS2-G15T3-2 has the highest grain yield by weight of 92.01 g.

Table 7. Yield per plant mentik susu rice result gamma 200 Gy ray irradiation

Strain M4	Lowest (G)	Supreme (G)	Range	Average
M-MS2-G15T3-2	41.00	92.01	41.00 to 92.01	66.51 ± 25.51 *
M-MS2-G15T3-4	36.86	56.65	36.86 to 56.65	46.76 ± 9.89 *
M-MS2-G15T3-5	42.36	69.98	42.36 to 69.98	56.17 ± 13.81 *
M-MS2-G15T3-7	44.96	61.99	44.96 to 61.99	53.47 ± 8.51 *
M-MS2-G15T3-8	57.02	76.96	57.02 to 76.96	66.99 ± 9.97 *
M-MS2-G15T4-24	35.64	64.38	35.64 to 64.38	50.01 ± 14.37 *
M-MS2-G16T5-7	40.96	64.54	40.96 to 64.54	52.76 ± 11.78 *
M-MS2-G5T7- 12	37.33	69.82	37.33 to 69.82	53.57 ± 16.24 *
M-MS2-G5T7- 16	46.15	75.05	46.15 to 75.05	60.60 ± 14.45 *
M-MS2-G13T20-12	38.81	73.44	38.81 to 73.44	56.13 ± 17.32 *
M-MS2-G13T20-29	41.73	75.24	41.73 to 75.24	58.49 ± 16.76 *
M-MS2-G18T7- 4	49.24	80.78	49.24 to 80.78	65.01 ± 15.77 *
M-MS2-G18T7- 6	46.45	76.41	46.45 to 76.41	61.43 ± 14.98 *
M-MS2-G18T7- 7	43.94	63.49	43.94 to 63.49	53.72 ± 9.78 *
M-MS2-G17T7- 10	49.28	76.34	49.28 to 76.34	62.81 ± 13.53 *
M-MS2-G17T7- 11	43.84	53.06	43.84 to 53.06	48.45 ± 4.61 *
M-MS2-G17T7- 13	33.63	62.58	33.63 to 62.58	48.11 ± 14.48 *
M-MS2-G17T7- 15	39.05	47.04	39.05 to 47.04	53.05 ± 13.99 *
CONTROL	24.76	36.51	24.76 to 36.51	24.76 ± 36.51

Numbers followed by sign (*) significantly different from the control based on the results of t test with $\alpha = 0.05$

3.8 Selection of M4

Based on individual selection, mentik susu rice M4 generation 200 Gy with irradiation resulted in 25 mutant plants which were selected by criteria have short-stemmed and have high productivity. The result of the selection of 25 plants have an average high range of 72- 84 cm. Strain M-MS2- G15T3- 2 with the number 25 is the best selection of plants that have the lowest plant height is 72 cm. Selection results also seen by productivity gains. Strain M-MS2- G15T3- 2 with the number 19, which has the highest productivity gains is to have the results of planting seed yield as much as 129.67 g. Mutation resulted shorter plants [22] and the productivity of rice plants irradiated at doses of 100 to 200 Gy can provide a higher yield than the control plants [23].

Table 8. Selection of M4

No.	Strain M4	Number of Plants Selected	Plant Height(cm)	Seed Yield Planting(g)
1	M-MS2- G15T3-2	5	81	88.39
		19	82	129.67
		25	72	60.54
2	M-MS2- G15T3-4	7	76	70.30
		28	80	56.88
3	M-MS2- G15T3-5	21	83	56.73
4	M-MS2- G15T3-7	18	77	40.97
		28	78	48.88
5	M-MS2- G15T3-8	5	79	45.14
6	M-MS2- G15T4-24	10	83	79.08
7	M-MS2- G13T20-12	4	82	69.09
8	M-MS2- G13T20-29	17	84	55.63
		27	83	43.72
9	M-MS2- G18T7-4	4	81	54.96
		5	83	88.90
		9	83	85.81
		24	84	82.92
10	M-MS2- G18T7-6	19	83	75.32
		24	80	69.10
11	M-MS2- G18T7-7	11	78	43.39
		24	82	69.63
12	M-MS2- G18T7-10	5	84	83.62
13	M-MS2- G18T7-11	24	84	53.22
14	M-MS2- G17T7-15	2	79	88.81
		10	76	56.62

Source: Results of selection

4. Conclusions

The conclusion of the research is rice plants of mentik susuM4 generation results 200 Gy of gamma ray radiation has a high performance of the plants, harvesting age, number of productive tillers, 100-grains weight and grains yield per plant better than the control (without radiation). There were 25 individual selected mutant strains of mentik susuM4 generation results 200 Gy of gamma radiation that has the character of a short stem and has a higher productivity than the control (without radiation).

Acknowledgment

The authors would like to thank everyone who participated in this research, especially to Faculty of Agriculture of Universitas Sebelas Maret.

References

[1] Yunus A, Parjanto and Pratama IY 2018 *IOP Conference Series: Earth and Environmental Science* **142**
[2] Badan Litbang Pertanian 2011 *Warta Penelitian dan Pengembangan Pertanian* **33**7–8
[3] Soeranto H 2003 *Proceedings of the Meeting and Scientific Presentation of the Basic Research of Nuclear Science and Technology* (Yogyakarta: P3TM-BATAN) 8 Juli 2003 pp 308–316ISSN 0216-3128
[4] Kumar DP, Chaturvedi A, Sreedhar M et al 2013 *Asian J Exp. Bioi. Sci.***4** 129–133 ISSN 0975-5845.

[5] Dessy R,Yunus A and Parjanto 2017 *Selection of M4 Mentik susu short stemmed mutations resulted from gamma ray irradiation* Skripsi (Surakarta: Universitas Sebelas Maret)
[6] Muliata IGP, Sudartha M and Santoso BB 2012 *Prosiding INSINAS* (Bandung) 29 November 2012 pp 1-7
[7] Harding SS, Johnson SD, Taylor DR, Dixon CA and Turay MY 2012 *American Journal of Experimental Agriculture*
[8] Haris A, Abdullah, Bakhtiar et al 2013 *J Scientific Research* **15** 1160–1164 DOI:10.5829/idosi.mejsr-.2013.15.8.11541.
[9] Patnaik D, Chaudhary D and Rao G J N 2011 *Plant Mutation Reports* **1** 11–16
[10] Warman B, Sobrizal, Suliansyah I et al 2015 *A Scientific Application of Isotopes and Radiation* **11** 125–135 ISSN:1907-0322.
[11] Yuniati MP 2011 *J Agron Ind* **39** 147–152
[12] New K T 2010 *Plant Mutation Reports* **1**34–36
[13] Nurcahyani V, Sumarno and Sudadi 2011 *J Ilmu Tanah dan Agroklimatologi* **11**
[14] Mugiono 2001 *Plant breeding using mutation techniques* (Jakarta: Batan Education and Training Center)
[15] Wang X, Lee S, Wang J, Ma J, Bianco T and Jia Y 2014 Current advances on genetic resistance to rice blast disease Chapter 7 in *Rice-Germplam, Genetics and Improvement* Available online at: 15 August 2018.
[16] Amri A, Sabaruddin and Rahmawati M 2016 *J Ilmiah Mahasiswa Pertanian Unsyiah* **1** 124–137
[17] Adimiharja J, Kartahadimaja J and Syuriani EE 2017 *J Penelitian Pertanian Terapan* **17** 33–39
[18] El-Degwy I S 2013 *International Journal of Agriculture and Crop Sciences*ISSN:2227-670X
[19] Do K T, Dao M S, Hung P Q et al. 2006 *Plant Mutation Reports***1**49–53
[20] Kristamtini, Setyorini W and Sutarno et al 2016 *Proceedings of the national seminar on agricultural genetic resource s*pp 90–100
[21] Sugiono D and Saputro N W 2016 *J Agrotek Indonesia***1**105–114. ISSN: 2477-8494
[22] Sobrizal 2016 *J Ilmiah Aplikasi Isotop dan Radiasi* **12** 23–36.
[23] Sasilakala R and Kalaiyarasi R 2010J *Plant Breeding* **1** 885–9.