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Yield Performance of Short-Stem Promising Mutant Lines of Mentik Wangi Paddy

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Abstract
The demand for paddy in Indonesia continues to increase, while production has decreased. As a solution, plant breeding through gamma irradiation with a dose of 200 gray on *Mentik Wangi* paddy can improve undesirable genetic traits, such as plant height and low yield, to produce superior varieties. This study aims to evaluate the yield potential of promising mutant strains with 200 gray gamma irradiation on mentik wangi paddy and obtain mutant strains with superior criteria for short-stemmed, short-lived, and high-yielding. The method used was a Randomized Complete Group Design (RCBD) with a single factor, namely strains consisting of 14 mutant strains, M6-200-G29-11-98-15 (G1), M6-200-G59-3-30-3 (G2), M6-200-G59-3-30-7 (G3), M6-200-G59-3-30-12 (G4), M6-200-G 59-18-1-2 (G5), M6-200-G59-18-1-13 (G6), M6-200-G59-18-43-7 (G7), M6-200-G59-18-43-16 (G8), M6-200-G107-17-60-3 (G9), M6-200-G107-17-60-23 (G10), M6-200-G147-2-48-19 (G11), M6-200-G17-2-55-1 (G12), M6-200-G147-2-55-8 (G13), M6-200-G147-10-76-14 (14) and 1 control strain with 3 replications. The observation variables included plant height (cm), total tillers, number of productive tillers, flowering age, harvesting age, panicle length (cm), number of seeds per panicle, panicle density index, weight of 100 seeds (g), and productivity (t.h^{-1}). Data was analyzed by Analysis of Variance (ANOVA) at the 5% error level, and if significant, was continued with *Duncan's Multiple Range Test* (DMRT) at the 5% error level. The result showed that all tested strains produced the expected superior criteria: short stem, short age, and high productivity.

Keywords: gamma irradiation; harvest age; local varieties; paddy

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Introduction

Paddy (*Oryza sativa* L.) is an important cultivated crop for more than half of the world's population, especially in Indonesia, because it is a food source. According to (1), paddy is also a paddy-producing food crop commodity that is vital to Indonesia's economic life. The demand for paddy in Indonesia will continue to increase along with the increasing population. Still, paddy production has begun to decline from year to year, leading to unmet national paddy needs. Based on (2), paddy production needs to be increased to meet the demand for paddy.

Efforts are made to meet the demand for paddy by encouraging activities to increase the yield of local varieties of paddy. One type of local variety widely favored by the community is mentik wangi paddy from Magelang, Central Java, Indonesia. According to (3), this aromatic variety of mentik wangi paddy has weaknesses, namely low productivity, and is less resistant to pests and diseases. Another Mentik Wangi paddy has several disadvantages, including a long maturation period, tall plant stature, and low yield. According to (4), the harvest age of fragrant mentik wangi paddy is about 125 days (4 months), and there is low harvest production of about 4-5 t./ha^{-1}.

To overcome this, plant breeding activities are carried out. According to (5), plant breeding to improve the quality and quantity of fragrant mentik can be done by gene mutation. According to (6), the development of plant breeding has been widely carried out, one of which is with modern techniques, namely irradiation.

Mutation induction using gamma radiation effectively produces new traits such as higher seed production, plants becoming more tolerant to biotic and abiotic stresses, and improved yield quality such as seed production. The study aimed to determine the yield power of promising strains by testing 14 mutant strains of fragrant mentik paddy varieties expected to produce new paddy strains with short-stemmed, short-lived, and high-yielding characters.

Materials and Methods

This research was conducted in Ngampel Hamlet, Gentungan Village, Mojogedang District, Karanganyar Regency, Central Java Province, June-October 2023. The paddy fields used were 253 m above sea level with a land area of 250 m^2 and Lithosol soil type. The tools used in the research included tractors, hoes, sickles, seedling trays, meters, scissors, analytical scales, and cameras. The materials used included urea fertilizer, NPK fertilizer, manure, and pesticides, control fragrant paddy elders (without radiation) as a comparison, and fragrant paddy strains (M6) resulting from 200 gray gamma radiation, as many as 14 mutant strains. The following strains were used: control (G0), M6-200-G29-11-98-15 (G1), M6-200-G59-3-30-3 (G2), M6-200-G59-3-30-7 (G3), M6-200-G59-3-30-12 (G4), M6-200-G 59-18-1-2 (G5), M6-200-G59-18-1-13 (G6), M6-200-G59-18-43-7 (G7), M6-200-G59-18-43-16 (G8), M6-200-G107-17-60-3 (G9), M6-200-G107-17-60-23 (G10), M6-200-G147-2-48-19 (G11), M6-200-G17-2-55-1 (G12), M6-200-G147-2-55-8 (G13), M6-200-G147-10-76-14 (14).

The method used was a non-factorial Completely Randomized Design (CRD) of strains with 3 replications. Each strain in each block was planted with 30 plants, totaling 1350. The planting distance used was 50 cm for each block and 25 x 20 cm for each plant strain in one block. Observations were made using the *sampling* method by randomly selecting 5 plant samples from each strain, resulting in 225 individual plants. The research stages comprised land preparation, nursery, planting, maintenance and care, harvesting, and post-harvest. The observation variables included plant height (cm), total tillers, number of productive tillers, flowering age, harvesting age, panicle length (cm), number of seeds per panicle, panicle density index, weight of 100 seeds (g), and productivity ($t.h^{-1}$). The data obtained were analyzed using *Analysis of Variance* (ANOVA) at the 5% error level; if there were significant differences, it was continued with *Duncan's Multiple Range Test* (DMRT) at the 5% error level.

Result and Discussion

Table 1. Summary of Growth and Yield of Mentik Wangi Paddy Irradiated with 200 Gray Gamma Rays

Line	Plant Height (cm)	Productive Tiller (stem)	Harvest Age	Productivity (tons ha^{-1})
M7-200-G29-11-98-15	105.63 a	23.07 a	100.33 bcd	7.95 h
M7-200-G59-3-30-3	102.46 a	28.07 c	99 ab	8.49 j
M7-200-G59-3-30-7	101.88 a	22.6 a	99.67 abc	7.07 cd
M7-200-G59-3-30-12	105.72 a	23.47 a	99.33 ab	7.43 g
M7-200-G 59-18-1-2	103.33 a	27.2 bc	99 ab	8.43 ij
M7-200-G59-18-1-13	105.03 a	22.8 a	99.33 ab	6.91 b
M7-200-G59-18-43-7	105.08 a	22.67 a	101 cd	7.36 fg
M7-200-G59-18-43-16	106.58 a	23.53 a	99.67 abc	7.82 h
M7-200-G107-17-60-3	104.20 a	29.07 c	98.33 a	8.55 j
M7-200-G107-17-60-23	104.81 a	24.33 ab	99.67 abc	8.32 i
M7-200-G147-2-48-19	105.13 a	22.6 a	101.33 d	6.97 bc
M7-200-G17-2-55-1	105.22 a	22.27 a	99 bc	7.19 de
M7-200-G147-2-55-8	104.32 a	23.07 a	100.33 bcd	6.86 b
M7-200-G147-10-76-14	106.04 a	23,37 a	98.67 a	7.27 ef
Control	111.97 b	20.6 a	111 e	5.52 a

Notes: Numbers followed by the same letter indicate not significantly different according to DMRT analysis at the $\alpha = 5\%$ level.

Plant Height

The short-stem mutant paddy variety mentik wangi significantly affected the height of the paddy plant. Based on Table 1, the plant height of the short-stem mutant hopeful strains of fragrant mentik paddy has better results than the control plants, characterized by a lower height (short) than the control plants (elders), and the difference is significant. (7) argue that the provision of gamma irradiation affects plant height, showing that the greater the irradiation dose, the greater the decrease in plant height. According to (8), the decrease occurs because the irradiation can damage plants' chromosomes, disrupting plant growth and inhibiting metabolic processes that cause a reduction in plant height.

Table 1 shows that the height of the control paddy plant/without irradiation) (119.97 cm) is significantly different from all the short-stem mutant promising strains of fragrant mentik paddy irradiated with 200 gray gamma rays. The growth of paddy plant height is also influenced by several factors, namely internal factors and external factors. According to (9), external or environmental factors include sunlight, temperature, air humidity, nutrients, and microorganisms that interfere with plants.

Based on the observation results (Table 1), the average height of fragrant mentik paddy plants irradiated with 200 gray gamma rays ranged from 101.88 to 106.58 cm, with a comparison plant (control) of 111.97 cm. Plants resulting from gamma-ray irradiation with 200 gray, with the lowest average plant height, were found in the M7-G59-3-30-7 strain (101.88 cm), while the highest plant height was found in the M7-G59-18-43-16 strain (106.58 cm). According to (10), paddy plant height is divided into three groups: short (<110 cm), medium (110-130 cm), and tall (>130 cm). Meanwhile, according to (11), the ideal paddy plant height ranges from 90 cm to 100 cm. (12) added that the plant height is perfect for maximum yield.

Based on the data obtained in Table 1, the height of paddy plants resulting from gamma-ray irradiation of 200 gray is classified in the category of short plant height. Still, it has not reached the ideal plant height because it exceeds 100 cm, but there is a decrease in plant height due to gamma-ray irradiation compared to control plants, and it shows better results than control plants.

Plants exposed to gamma-ray irradiation showed better results compared to the control. According to (13), paddy plants that are too tall will easily fall, which can reduce paddy yields. Meanwhile, according to (14), paddy plants that are too short will make harvesting difficult.

Number of Productive Tillers

The results of the ANOVA analysis test showed that the short-stem mutant, a promising strain of fragrant mentik varieties, significantly affected the number of productive tillers of paddy plants. According to (15), productive tillers are one of the yield components that directly affect the high and low grain yield. Based on the results (Table 1), the fragrant paddy short-stem mutant hope lines produced more productive tillers than the control plants. The hopeful strains of fragrant mentik paddy have more productive tillers and are significant based on the DMRT test at the 5% α level. This can occur because mutations occur due to the provision of gamma irradiation, increasing the number of irradiated tillers compared to control plants. According to (16), mutation breeding helps improve some mutant traits without changing most of the original mutant characteristics. According to (17), gamma irradiation can affect plant growth and development by changing physiological, biochemical, and genetic processes and causing changes in cell morphology.

Based on the results obtained, the number of productive tillers in control plants (without irradiation) was not significantly different from all the short-stem mutant strains except strains M7-200-G59-3-30-3 (28.07 stems), M7-200-G59-18-1-2 (27.2 stems), and M7-200-G107-17-60-3 (29.07 stems). Strain M7-200-G107-17-60-3 has the highest average number of productive tillers at 29.07 stems, while the strains with the least number of productive tillers are M7-200-G17-2-55-1 at 22.27 stems, and the control plants have an average number of productive tillers of 20.6 stems. According to (18), the difference in yield in mutant paddy can occur due to variations in the response of each genotype to the irradiation given. According to (19), mutation causes the number of paddy tillers to increase due to changes in gene expression.

All short-stem mutant strains of mentik wangi paddy have many productive tillers because they have an average number of productive tillers of more than 15 (22.27-29.07 stems). According to (20), the number of productive tillers is categorized into three groups, namely: few (less than 10 productive tillers), medium (10-15 productive tillers), and many (more than 15 productive tillers). The number of productive tillers directly affects the number of panicles produced increases because the more productive tillers, the higher the amount of grain that will be obtained, and according to (21), the increase in the number of tillers occurred along with the increasing dose of irradiation.

Harvest Age

The results of the ANOVA analysis test showed that the short-stem mutant, a promising strain of fragrant mentik paddy varieties, significantly affected the harvest age of paddy plants. The hopeful strains of fragrant mentik paddy have a faster flowering age and are real based on the DMRT test at the 5% α level. The speed of flowering plants influences the age of the plant. According to (22), 200 gray gamma radiation produces mutant plants with a higher and faster flowering age than those without gamma radiation. According to (23), the acceleration of harvest age occurs because of the acceleration of plants to release flowers or the shortening of the generative growth phase. Another opinion, according to (24), is that gamma radiation treatment given to plants can affect cells' ability to produce early-maturing plants. Meanwhile, according to (25), mutagenesis using gamma rays improves many valuable traits that affect plant size, flowering time, harvesting and ripening time, and resistance to pathogens.

Based on the results, the control plants (without irradiation) were significantly different from all the short-stem mutant promising strains of fragrant mentik wangi paddy irradiated with 200 gray gamma rays. The paddy plants ready to harvest are calculated after planting, with the criteria that 85%-90% of the grain has turned yellow and filled. According to (20), the characteristics of paddy that is ready to be harvested are paddy grains and flag leaves that have turned yellow, stalks ducked because they are loaded to bear paddy grains or grains that are getting heavier, paddy grains when pressed feel complex and complete and if peeled are not greenish or white relatively soft like chalk.

Mentik wangi paddy irradiated with 200 gray gamma rays has an average harvest age of 98.33 and 101.33 days after planting. According to (26), the harvest age of each genotype is influenced by genetic factors and the environment. Good vegetative and generative phases can determine the early harvest age of paddy. Line M7-200-G107- 17-60-3 is a mutant line with the shortest harvest age (98.33 day after planting) and line M7-200-G147-2- 48-19 is a mutant line with the longest harvest age. A shorter paddy age tends to be more desirable for farmers because it can be harvested sooner, which increases the next harvest period and minimizes the occurrence of bad possibilities such as pest attacks and poor climatic conditions. Control lines without gamma irradiation treatment had an average harvest age of 111 days after planting. Based on these results, it was found that the results of 200 gray gamma irradiation on fragrant mentik paddy produced the desired superior trait of faster harvest age.

Productivity

Anova analysis test results showed that the short-stem mutant, a promising strain of fragrant mentik paddy varieties, significantly affects the productivity of paddy plants. Productivity measures the paddy yield obtained per unit land area in one planting period. According to (27), the amount of paddy yield per hectare is determined by its production components. These components consist of the number of seeds per panicle, the number of panicles per clump, the weight of 1000 seeds, and the percentage of filled grain. Based on Table 1, the productivity of the short-stem mutant promising strain has better results than the control plants without treatment. (28) mentioned that high productivity can be achieved if the panicle produces a lot of filled grain.

The hopeful strains of fragrant mentik paddy have heavier productivity results, and are real or significant based on the DMRT test at the α = 5% level. According to (29), giving gamma rays to plants can increase plant productivity compared to plants without treatment. This shows that gamma irradiation gives a positive response and can improve. According to (30), gamma-ray treatment significantly affected grain production with a good radiation dose for paddy plants between 200 and 300 gray. This means that giving a dose of gamma radiation of 200 gray gives good results on the productivity of fragrant mentik paddy plants. (31) shows that gamma irradiation mutants have high production. Meanwhile, according to (32), the productivity of 200 gray mutants is higher than that of the mutants of irradiation doses of 100 and 300 gray.

The productivity of the gamma-irradiated short stem mutant promising strain for the highest yield was found in the M7-200-G107-17-60-3 strain (8.55 tons.$^{ha-1}$), while the lowest yield was found in the M7-200-G147-2-

55-8 strain (6.86 tons.$^{ha-1}$). The control line without treatment had a productivity of 5.52 tons $^{ha-1}$. The observation results showed a difference in the productivity of fragrant mentik paddy plants. The difference in production can be caused by the genetic composition of each paddy cultivar, according to Nurzannah et al. (2020), which includes factors that affect production, including land area, harvest area, and attacks of plant-disrupting organisms (OPT).

Conclusion

The hopeful strains of mentik wangi paddy tested have growth characteristics and superior criteria, as well as better yields than the elders (control plants) in the form of: low plant height (101.88 - 106.58 cm), large number of productive tillers (22.27-29.07 stems), short harvest age (98.67-101.33 day after planting), and high productivity (6.97-8.55 t.ha^{-1}). These lines can be used as a source of new diversity for further and multilocation testing and can be released as new varieties.

Conflicts of Interest

The author declares no conflict of interest.

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