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Assembly of Lowland Adaptive Wheat Mutant Through Gamma Ray Mutation Induction

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ABSTRACT

Wheat is the largest cereal food in the world's staple food supply. The expansion of the wheat crop needs to be done through extensification efforts in the lowlands to increase domestic production. The main obstacles faced in the lowlands are the high air temperature and the intensity of sunlight. The research objective was to provide adaptive wheat mutants in the lowlands, especially in North Sumatra. The seeds of 3 varieties of wheat: Dewata, Basribey, and G-21 were treated with gamma irradiation with a dose of 100, 200, 300, 400, 500, and 600 Gy. Each treatment was repeated three times. The highest percentage of germination and vigor index due to the combination of treatment of wheat varieties with gamma rays was the combination of Dewata and 200 Gy which was significantly different from Basribey and G-21. Gamma irradiation treatment of 100 Gy on the three mutant wheat varieties showed differences in plant height, namely the G-21 variety, followed by Dewata and Basribey. The number of productive tillers showed significant variation between the gamma-ray treatments for each mutant wheat genotype and the most productive tillers were at a gamma-ray dose of 100 Gy for all wheat genotypes. The 100 Gy gamma ray treatment caused the number of seeds of the Dewata variety to be much higher than that of Basribey and G-21. The mutants obtained with the desired characters are the basic materials in assembling new superior varieties of wheat that are adaptive in the lowlands.

Keywords: High Temperature; Irradiation; Mutant; Viability; Yield

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the largest cereal food in the world's staple food supply. The national demand for wheat reached 10.1 million tons in the 2020/2021 period, prompting the government to promote the mass planting of wheat. This is to reduce import capacity due to the increasing demand for wheat. The development of subtropical wheat in Indonesia is concentrated only in the highlands with a limited area (Tarigan and Syofia 2017), so wheat production development is directed to the lowlands. The obstacles faced in the lowlands are higher temperatures, but lower rainfall and humidity.

Water is necessary for photosynthesis, which is how plants use energy from the sun to create their food. During this process, plants use carbon dioxide from the air and hydrogen from the water absorbed through their roots and release oxygen as a byproduct. If the water requirement is met, then the process of photosynthesis in plants will run well and produce assimilates that can be translocated to fill the seeds (Gutschick 1997). Photosynthate supply is the main factor that directly determines seed yield (Egli 1993).

Genetic and environmental factors play a role in increasing the productivity of superior wheat (Praptana and Hermanto 2016). Therefore, the availability of varieties that suit the local environment and high yield potential are factors that directly affect the yield and adaptability of varieties to the environment. According to Erythrina and Zaini (2016), wheat produces well when grown in an environment with temperatures between 10-25°C and rainfall of 350-1250 mm during its life cycle and soil with a pH of 6-8.

Various breeding efforts are needed to increase the tolerance of wheat plants to abiotic environmental stresses such as high temperatures through genetic improvement. Utilization of genetic diversity through mutation induction is used in plant breeding programs to develop plant varieties that have certain character advantages. The purpose of mutation induction is to increase the rate of mutation frequency so that variants with a high level of diversity will be selected according to the desired character (Setiawan et al. 2015). Mutation breeding can also effectively change some traits without

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changing other traits that are already favored (Sobrizal 2017). Mutation induction can be done using chemical and physical mutagens. Gamma-ray irradiation is a type of physical mutagen commonly used to increase genetic diversity in various plants (Setiawan et al. 2015).

Tarigan (2017) has conducted research on wheat in the lowlands, namely in Diski, Deli Serdang, North Sumatra at an altitude of 85 meters above sea level. Tarigan's research showed that almost all (±85%) wheat plants that received gamma-ray treatment did not show good growth and development. This is presumably because the irradiated wheat seeds have not been able to adapt to the high-temperature environment. According to Erythrina and Zaini (2016), plants will develop slowly if the temperature and rainfall are too high because the anthesis process will be disrupted to produce seeds. In addition, the punctuality of planting time and the even distribution of rainfall in the growth phase also correlate with yields so that wheat seed production can be higher.

Efforts to accelerate the release of new superior varieties of wheat have been initiated in collaboration with the Agricultural Research and Development Agency through a research consortium involving several institutions such as the Agricultural Research and Development Agency (Cereal Crops Research Center, Biogen Center), universities (Institut Pertanian Bogor and Universitas Andalas) and PATIR-BATAN. Consortium research was carried out to form new superior tropical wheat varieties through adaptive conventional and non-conventional breeding activities in lowland to mediumland areas. Based on this, this study aims to obtain the appropriate dose of gamma rays for the growth and yield of wheat plants and to obtain mutant plants that are adaptive in the lowlands to produce optimal seeds. The results of this study are expected to contribute to the development of research in efforts to assemble new varieties to produce optimal seeds.

MATERIALS AND METHOD

The research was conducted in Medan at an altitude of 25 m asl (3°36'40.3'N 98°42'49.6'E), from June to September 2020. According to the Deli Serdang Climatology Station, the average rainfall is 286.5 mm/month; the temperature is 27.5°C; air humidity is 84.5%; and the intensity of sunlight is 166 W.m-2. Gamma-ray treatment was carried out at the Isotope and Radiation Application Center of the National Nuclear Energy Agency (PAIR-BATAN) with a source of gamma-ray radiation using Co^{60} from the Gamma Chamber. The materials used are wheat seeds namely Dewata, Basribey, and G-21 varieties.

Research procedure

An amount of 200 seeds per dose of the three varieties were irradiated with gamma rays, then 100 seeds were taken from each dose of irradiation and then sown in germination trays. The seeds were germinated for 3 days to observe the percentage of germination and vigor index. After the seeds germinated, the wheat sprouts were planted in the field using polybags filled with topsoil as the planting medium. Planting one seed per polybag and rearing it until it grows and the grain is full to analyze the yield of mutant wheat in the first generation (M1).

The study used a factorial complete randomized block design with three replications. The first factor is the gamma irradiation dose which consists of four levels: S1 = 100 Gy, S2 = 200 Gy, S3 = 300 Gy, S4 = 400 Gy, S5 = 500 Gy, S6 = 600 Gy. The second factor was wheat which consisted of 3 (three) varieties namely Dewata (L), Basribey (I), and G-21(F).

Parameters observed were growth and yield of mutant wheat in the first generation (M1), including germination percentage, vigor index, plant height, leaf area, total chlorophyll, number of productive tillers, flowering age, panicle length, number of spikelets per panicle, and number of seeds per panicle.

The percentage of germinated seeds is calculated by the formula:

$$\text{Percentage of germinated seeds} = \frac{\text{Number of seeds grown}}{\text{Number of seeds planted}} \times 100\%$$

The vigor index is calculated based on the percentage of seeds that grow normally on the third day. The vigor index is calculated by the formula:

$$\text{Vigor index} = \frac{\text{Number of normal sprouts on the third day}}{\text{Number of seeds planted}} \times 100\%$$

Plant height was measured from the base of the stem to the top of the highest leaf at 12 weeks after planting (WAP). The leaf area measurement was carried out by calculating the p x l x constant (0.75) by taking flag leaves from each treatment 12 weeks after planting (WAP). Leaf chlorophyll measurements were carried out using a chlorophyll meter at 12 WAP. The age of flowering is calculated when the wheat plants have reached 80% flowering. The number of productive tillers is counted for tillers with panicles and the number of seeds per panicle is counted for all seeds formed in panicles which are carried out at the time of harvest. Panicle length is measured by measuring from the base to the tip of the panicle using a tape measure. The number of spikelets per panicle is calculated by counting each spikelet formed in the panicle, where one spikelet usually consists of five seeds. The number of seeds per panicle is calculated with all the seeds formed in the panicle.

Data analysis

Observational data were analyzed using ANOVA (analysis of variance) and the average was tested further with Duncan's multiple range test (DMRT) at 5% level using the software SAS ver. 9.

HASIL DAN PEMBAHASAN

Germination percentage and vigor Index

Gamma irradiation treatment caused the germination percentage of the three wheats to be significantly different. The highest germination percentage was obtained at 200 Gy of gamma irradiation, however, with increasing gamma irradiation up to 600 Gy, the percentage of seeds that germinated decreased for the three wheat genotypes tested. Gamma irradiation treatment of the three wheat seed genotypes caused significantly different germination vigor indices. Dewata variety seeds had a much higher vigor index than G-21 and Basribey (Table 1).

Table 1. Effect of treatment of wheat varieties and gamma rays on germination percentage and vigor index of the wheat mutant on the 3rd day

Mutant	Dose of gamma-ray irradiation (Gy)					
	100	200	300	400	500	600
	Germination percentage					
G-21 (F)	90^{b}	80^{c}	80^{c}	60^{e}	50^{f}	40^{g}
Basribey (I)	80^{c}	90^{b}	80^{c}	70^{d}	50^{f}	40^{g}
Dewata (L)	90^{b}	100^{a}	90^{b}	70^{d}	60^{e}	50^{f}
	86.67±5.8	90±10	83.33±5.8	66.67±5.80	53.33±5.80	43.33±5.8
	Vigor index (%)					
G-21 (F)	80^{c}	80^{c}	80^{c}	60^{d}	50^{e}	40^{f}
Basribey (I)	80^{c}	80^{c}	80^{c}	60^{d}	40^{f}	30^{g}
Dewata (L)	90^{b}	100^{a}	80^{c}	60^{d}	60^{d}	40^{f}
	83.33±5.80	86.67±11.5	80.00±0.00	60.00±0.00	50.00±10.00	36.67±5.80

Note: Numbers followed by the same letter were not significantly different in Duncan's Multiple Range Test (DMRT) at 5%

Based on Table 1, the higher the irradiation, the lower the percentage of germination on the third day of observation after germination. The higher gamma-irradiation doses inhibited the cell's vital functions eventually leading to the death of the embryo or certain cells in the seeds (Muhammad et al. 2021). The percentage of germination was significantly different in the combined treatment of wheat varieties with 200 Gy gamma rays. The highest germination was obtained for the Dewata variety, namely 100%, followed by Basribey (90%) and G-21 (80%). According to Iglesias-Andreu et al. (2012), seed quality improvement can be carried out by utilizing gamma irradiation techniques to increase seed viability and vigor.

The combination of wheat varieties and gamma irradiation resulted in a significant difference in growth percentage. The combination of Dewata irradiation and 200 Gy gamma rays produced the highest seed germination of 100%. However, the germination percentage decreased due to increasing gamma ray treatment for all wheat varieties. The decrease in germination percentage is thought to be due to the effect of gamma rays on the meristematic tissue of grains. According to (Dhakshanamoorthy et al. 2010), decreased grain germination at higher doses of mutagens can be associated with disturbances at the cellular level on a physiological as well as physical level. Marcu et al. (2013) stated that high doses of irradiation could reduce seed germination. Furthermore, Ussuf and Nair (1974)said that gamma irradiation interfered with enzyme synthesis and at the same time accelerated the degradation of enzymes involved in the formation of auxins, thereby reducing seed germination.

Similar to the germination percentage, the highest vigor was also obtained for the combination of Dewata and 200 Gy reaching 100%, while Basribey and G-21 had significantly lower vigor indexes. Increasing the dose of irradiation will reduce the vigor index of all seeds in the varieties tested. Exposure to gamma irradiation will affect the activity of body cells and can even damage the DNA structure in the chromosomes. This is by the statement of Gaswanto et al. (2016) that irradiation will have a direct impact on the chromosomes by damaging the chromosome arrangement or changing one of the DNA bases. Irradiation can indirectly start a chain of physical and chemical reactions. Chromosomes are very sensitive to damage in prophase during the process of mitotic division. The frequency of living mutants increases linearly with gamma-ray dose.

Plant height and leaf area

Based on the research results, it is known that the dose of gamma rays has a significant effect on the plant height of each wheat mutant. Based on the data obtained, the 100 Gy gamma-ray treatment resulted in the highest plant growth, but the plants were shorter when given the 300 Gy gamma-ray treatment, even the plants died in the 400-600 Gy. Gamma-ray treatment with different doses also showed differences in the leaf area of each wheat mutant. Gamma-ray with a dose of 100-300 Gy gave varied and significantly different leaf areas, but a dose of 400-600 Gy caused the plant's death (Table 2).

Gamma-ray treatment of 100 Gy on the three mutant wheat varieties caused significant differences in plant height. The tallest plant was obtained for G-21 (58 cm), followed by Dewata (55 cm) and Basribey (51 cm). The highest plant among wheat varieties was the combined treatment of G-21 (F) and 100 Gy. Gamma-ray treatments of 200 Gy and 300 Gy significantly reduced plant height in the three wheat mutants. Even irradiation of 400-600 Gy caused the seeds to die on observation 12 weeks after planting. This shows that the higher the dose, the more inhibited plant growth both plant height and the size of plant parts.

Table 2. Effect of treatment of wheat varieties and gamma rays on plant height and leaf area of the wheat mutant at two weeks after planting

Mutant	Dose of gamma-ray irradiation (Gy)					
	100	200	300	400	500	600
			Plant height (cm)			
G-21 (F)	58[a]	47[d]	39[g]	0[i]	0[i]	0[i]
Basribey (I)	51[c]	42[f]	35[h]	0[i]	0[i]	0[i]
Dewata (L)	55[b]	45[e]	38[g]	0[i]	0[i]	0[i]
Average	54.67±3.50	44.67±2.50	37.33±2.10	0.00±0.000	0.00±0.000	0.00±0.000
			Leaf area (cm^2)			
G-21 (F)	22.07b	20.12c	15.07h	0j	0j	0j
Basribey (I)	18.24e	16.80g	14.96i	0j	0j	0j
Dewata (L)	22.61a	18.54d	18.00f	0j	0j	0j
Average	20.97±2.40	18.49±1.70	16.01±1.70	0.00±0.00	0.00±0.000	0.00±0.000

Note: Numbers followed by the same letter were not significantly different in Duncan's Multiple Range Test (DMRT) at 5%

According to Yunita et al. (2014), irradiation dose is one of the factors that influence genetic changes in plant cells, where high irradiation doses can result in tissue death, while low irradiation doses will cause abnormal changes in plant phenotypes. Gaswanto et al. (2016) also stated that plant height growth will be affected by gamma irradiation. In line with the results of the research by Minisi et al. (2013), the highest plants were obtained at low doses of gamma irradiation. Conversely, increasing the radiation dose to plants will reduce plant height. Dhakshanamoorthy et al. (2010) explained that chromosomes are very sensitive to damage in the mitotic division during prophase and increasing the dose of mutagens will also increase disturbances at the cellular level and its development both physiologically and physically.

Based on Table 2, it can also be seen the effect of gamma irradiation on leaf area, where the Dewata variety has the widest leaves (22.61 cm) and is significantly different compared to G-21 varieties (22.07 cm) and Basribey (18.24 cm) with 100 Gy gamma-ray irradiation. Increasing the dose of gamma rays will significantly reduce leaf area for all varieties tested. Even the addition of an irradiation dose of 400-600 Gy causes the plant to die. According to Yunita et al. (2014), genetic changes and phenotypes of irradiated seeds can occur due to increased doses of gamma rays causing changes in cell and tissue structure that affect the appearance and yield of plants. In line with De Micco et al. (2011), radiation exposure has direct and indirect effects on seed germination, growth, and reproduction of plants by changing cellular and tissue structures that cause different genetic and phenotypic abnormalities. Furthermore, exposure to gamma radiation at higher doses can kill the cells in the seeds, reduce the length of roots and shoots, fresh weight of roots and shoots. However, low doses of gamma rays have a stimulating effect on the average leaf length and width (Amirikhah et al. 2021).

Total chlorophyll and flowering age

Gamma-ray irradiation affected the total chlorophyll of the wheat mutant. Gamma irradiation of 100-300 Gy produced significantly different total chlorophyll in the three mutants tested, however, gamma-ray of 400-600 Gy caused the plant's death. In addition, gamma-ray irradiation also affected the flowering age of wheat plants, where mutants given a gamma-ray dose of 100 Gy caused a significantly faster flowering age than the 200 and 300 Gy irradiation doses (Table 3).

The total chlorophyll of the Dewata variety (8.77 mg.g^{-1}) was more numerous and significantly different than the G-21 mutant (6.55 mg/g) and Basribey (5.89 mg.g^{-1}) with an irradiation dose of 100 Gy. The higher the dose of gamma irradiation will decrease the total chlorophyll of wheat leaves. One of the causes of a decrease in the amount of chlorophyll is related to a decrease in the mitotic activity of meristematic cells and disturbances in physiological and biochemical properties (Asare et al. 2017). This shows that the application of high doses of gamma rays in irradiation can have harmful effects on plants. High doses of gamma radiation reduce photosynthetic activity, thereby reducing chlorophyll content and plant growth (Marcu et al. 2013).

In addition, the gamma irradiation treatment with a dose of 100 Gy caused a significantly different flowering time. The Dewata variety (54 days) has a shorter flowering time than Basribey (56 days) and G-21 (58 days). Research by Aisyah et al. (2005) using gamma rays showed that gamma radiation doses of 50 and 55Gy affected the flowering period of jasmine (*Jasminum* spp.). The results of this study indicate that the application of low doses of gamma rays stimulates faster flower growth. According to Khatab and Hegazi (2015), the initiation of flowering may be affected because of mutagenic treatments because many biosynthetic pathways are believed to be altered, which are directly as well as indirectly associated with flowering physiology.

Table 3. Effect of treatment of wheat varieties and gamma rays on total chlorophyll and flowering age of the wheat mutant

Mutant	Dose of gamma-ray irradiation (Gy)					
	100	200	300	400	500	600
			Total chlorophyll (mg.g^{-1})			
G-21 (F)	6.55b	5.88d	5.36f	0h	0h	0h
Basribey (I)	5.89d	5.43e	5.04g	0h	0h	0h
Dewata (L)	8.77a	5.96c	5.33f	0h	0h	0h
Average	7.07±1.50	5.76±0.30	5.24±0.20	0.00±0.00	0.00±0.00	0.00±0.00
			Flowering age (day)			
G-21 (F)	58a	55bc	51e	0f	0f	0f
Basribey (I)	56b	53d	50e	0f	0f	0f
Dewata (L)	54cd	53d	53d	0f	0f	0f
Average	56.00±2.00	53.70±1.2	51.30±1.50	0.00±0.00	0.00±0.00	0.00±0.00

Note: Numbers followed by the same letter were not significantly different in Duncan's Multiple Range Test (DMRT) at 5%

Number of productive tillers and panicle length

The number of productive tillers showed significant variation between gamma-ray treatments for each wheat mutant. The highest number of productive tillers was found at a dose of 100 Gy for all wheat varieties, although it was not significant. However, an increase in gamma rays of 200 Gy decreases the number of tillers. Furthermore, increasing the gamma-ray to 400-600 Gy caused the wheat mutant not to produce tillers. The panicle length of the wheat mutant given several doses of gamma rays showed a significant difference, where the higher the dose of gamma rays given tended to decrease the panicle length although the difference was not significant (Table 4).

A dose of 100 Gy of gamma-ray produced 2 tillers, not significantly different in all the tested mutants. However, an increase in the gamma irradiation dose of 200 Gy led to a significant decrease in the number of tillers. G-21 and Basribey varieties only had 1 tiller, while Dewata was still able to produce 2 tillers. Yunus et al. (2018) reported that the number of productive tillers at a dose of 100 Gy gamma rays had a higher number of productive tillers, namely 16 tillers in rice plants, while the least number of tillers was the treatment with a 300 Gy gamma-ray dose of 13 tillers. This shows that the higher the dose of gamma rays will decrease the number of productive tillers.

Gamma-ray irradiation with a dose of 100 G also caused differences in panicle length, where the longest panicle was obtained in the Dewata mutant (7 cm) which was significantly different from Basribey (5 cm) but not significantly different from G-21 (6 cm). An increase in the gamma-ray dose of 200 and 300 Gy caused a difference in the panicle length of the three mutants tested, although the difference was not significant. The difference in panicle length occurred in the administration of 100 Gy gamma rays. The difference in panicle length is because each variety has a different resistance to exposure to gamma radiation. According to Asare et al. (2017), decreased panicle length occurred simultaneously with the decreased mitotic activity of meristematic cells, auxin biosynthesis, changes in ascorbic acid levels, and metabolic disorders that could inhibit growth.

Number of spikelets and number of seeds per panicle

Gamma-ray irradiation at various doses caused significant differences in the number of spikelets per panicle in each wheat mutant. The higher the irradiation dose, the smaller the number of spikelets. The difference in the dose of gamma rays showed that the number of seeds per panicle was significantly different between the mutants. The 100 Gy gamma ray treatment produced the highest number of seeds compared to the higher dose (Table 5).

Irradiation treatment with a dose of 100 Gy produced spikelet numbers that were not significantly different between the three mutants tested. The highest number of spikelets per panicle was in the Dewata mutant (10 spikelets), followed by Basribey and G-21. Meanwhile, gamma irradiation with a dose of 200 Gy caused a significant difference in the number of spikelets per panicle in Dewata (9 spikelets) compared to Basribey (7 spikelets). In addition, the irradiation dose of 300 Gy caused the number of spikelets per panicle of Basribey to be significantly less (5) compared to G-21 and Dewata which each produced 7 spikelets per panicle. In irradiation doses of 400-600 Gy, plants do not grow because high doses of gamma irradiation are known to have a negative effect on the physiological and biochemical properties of plants (Jan et al. 2012), so the formation of spikelets and seeds is hampered and even plants die at high doses of gamma irradiation.

Table 4. Effect of treatment of wheat varieties and gamma rays on the number of productive tillers and panicle length of the wheat mutant

Mutant	Dose of gamma-ray irradiation (Gy)					
	100	200	300	400	500	600
	Number of productive tillers (tiller)					
G-21 (F)	2ᵃ	1ᵇ	0ᶜ	0ᶜ	0ᶜ	0ᶜ
Basribey (I)	2ᵃ	1ᵇ	0ᶜ	0ᶜ	0ᶜ	0ᶜ
Dewata (L)	2ᵃ	2ᵃ	1ᵇ	0ᶜ	0ᶜ	0ᶜ
Average	2.00±0.00	1.30±0.60	0.30±0.60	0.00±0.00	0.00±0.00	0.00±0.00
	Panicle length (cm)					
G-21 (F)	6ᵃᵇ	5ᵇ	5ᵇ	0ᶜ	0ᶜ	0ᶜ
Basribey (I)	5ᵇ	5ᵇ	5ᵇ	0ᶜ	0ᶜ	0ᶜ
Dewata (L)	7ᵃ	6ᵃᵇ	6ᵃᵇ	0ᶜ	0ᶜ	0ᶜ
Average	6.00±1.00	5.30±0.60	5.30±0.60	0.00±0.00	0.00±0.00	0.00±0.00

Note: Numbers followed by the same letter are not significantly different in Duncan's Multiple Range Test (DMRT) at 5%

Table 5. Effect of treatment of wheat varieties and gamma rays on the number of spikelets per panicle and number of seeds per panicle of the wheat mutant

Mutant	Dose of gamma-ray irradiation (Gy)					
	100	200	300	400	500	600
	The number of spikelets per panicle					
G-21 (F)	9ᵃᵇ	8ᵇᶜ	7ᶜ	0ᵉ	0ᵉ	0ᵉ
Basribey (I)	9ᵃᵇ	7ᶜ	5ᵈ	0ᵉ	0ᵉ	0ᵉ
Dewata (L)	10ᵃ	9ᵃᵇ	7ᶜ	0ᵉ	0ᵉ	0ᵉ
Average	9.30±0.60	8.00±1.00	6.30±1.20	0	0	0
	Number of seeds per panicle					
G-21 (F)	24ᶜ	17ᵉ	0ʰ	0ʰ	0ʰ	0ʰ
Basribey (I)	28ᵇ	11ᶠ	0ʰ	0ʰ	0ʰ	0ʰ
Dewata (L)	30ᵃ	19ᵈ	5ᵍ	0ʰ	0ʰ	0ʰ
Average	27.30±3.10	15.6±4.20	1.60±2.90	0.00±0.00	0.00±0.00	0.00±0.00

Note: Numbers followed by the same letter in the same column or row were not significantly different in Duncan's Multiple Range Test (DMRT) at 5%

Gamma ray treatment of 100 Gy caused the number of seeds of the Dewata mutant (30 seeds) to be much higher than that of Basribey (28 seeds) and G-21 (24 seeds). Increasing 200 Gy of gamma irradiation significantly reduced the number of seeds per panicle for all tested mutants. Even the gamma irradiation treatment of 400-600 Gy caused the wheat mutant to not produce seeds and the plants died. Several previous studies stated that high doses of gamma radiation reduced photosynthetic activity thereby reducing seed yields (Marcu et al. 2013). Besides, the use of low-quality seeds also causes plant growth to become non-uniform and reduces yield and quality (Widiastuti and Wahyuni 2020).

Wheat comes from sub-tropical regions, so it is necessary to modify the variety so that it can be developed in tropical regions, one of which is Indonesia. However, the constraints are the unavailability of local genetic resources and the limited introduction of genetic resources (Andriani et al. 2015). In addition, the constraints on wheat cultivation, which is generally in the highlands in Indonesia, must compete with horticultural crops that have higher economic value (Nur et al. 2017).

Therefore, it is necessary to increase the genetic resources of wheat and develop it so that its adaptability is wider, especially in the lowlands. Efforts to increase the genetic diversity of wheat through plant breeding are utilizing varieties or varieties that have adapted to specific environments so that opportunities to obtain wheat varieties that are more adaptive in the plains and medium are greater (Nur et al. 2017).

CONCLUSIONS

The combination of the Dewata variety with 200 Gy gamma irradiation showed the highest germination percentage and vigor index compared to the other combinations. Gamma irradiation of 100 Gy was the best treatment which caused significant differences in plant height, productive tillers, and number of grains per panicle in wheat mutants. The Dewata variety had higher productivity (number of productive tillers, panicle length, number of spikelets, and number of seeds per panicle) compared to Basribey and G-21. The Dewata variety is a candidate for lowland adaptive wheat mutant development.

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