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Selection for Growth Traits on M1V1 Generation of Raja Bulu Banana (*Musa paradisiaca* Linn.) Obtained by Gamma Rays Irradiation

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Abstract

Raja Bulu is one of the banana varieties favored by the community because of its thick fruit flesh and sweet taste. However, its parthenocarpic characteristic and vegetative propagation make this banana variety has limited genetic variation. Attempt to improve the genetic variation was conducted through induced mutation breeding using gamma-ray mutagens. This research aimed to select M1V1 generation of Raja Bulu banana (*Musa paradisiaca* Linn.) obtained by gamma rays' irradiation for their growth traits which are expected to produce banana varieties that have an early maturity and high yield. This study used a randomized complete block design without replication by observing the generative growth of each individual of Raja Bulu banana irradiated by gamma rays and without radiation as a control. The results showed that gamma-ray irradiation treatment caused Raja Bulu banana to be harvested earlier and produced higher fruit weight than controls. The gamma-ray irradiation had a random influence on Raja Bulu bananas. The 10 Gy gamma-ray irradiation dosage influenced the morphological diversity in the generative phase of Raja Bulu banana. The treatment of gamma irradiation resulted in 5 individual plants that flowered and matured earlier as compared to controls.

Keywords: breeding; early maturity; flowering date; genetic diversity; mutation

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INTRODUCTION

Banana is a type of tropical fruit that thrives in Indonesia due to the favorable climatic conditions. According to Rahayu et al. (2014) banana is a popular fruit and is widely favored by people from various backgrounds because the price of bananas is relatively cheap, easily cultivated and bananas can be harvested throughout the year. Banana fruit can be consumed by people at various growth stages and can be consumed at any time. According to data from the BPS - Statistics Indoensia (2019) the development of national banana production increased from 8.13 million tons in 2015; 8.18 million tons in 2016 to 8.36 million tons in 2017.

Raja Bulu banana is one of banana varieties which is popular in Indonesia. Ripe bananas can be directly consumed or processed in the form of dry or wet food. Bananas contain starch as a main source of energy-producing carbohydrates, vitamins and minerals. The sweet taste in addition to its richness in minerals such as potassium, magnesium, phosphorus, iron and calcium make many bananas popular among fruit consumers. Banana fruit also contains vitamins C and B complex as well as active serotonin; which is a neurotransmitter assisting in the function of the brain (Hasanah et al., 2017). Another advantage of Raja Bulu banana is its attractive visuals such as rather thick flesh, sweet taste and fragrant aroma (Soeseno, 2007).

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Raja Bulu banana (*Musa paradisiaca* Linn.) belongs to the triploid genome type. The shape of the Raja Bulu banana flower resembles a heart there is only one flower and resembles one house in a bunch with dark red barchetta (Salvador, 2012). The fruit is yellow on average with brown spots. The bunches of downy fruits consisted of 6-8 combs and each comb consisted of 12-13 pieces of bananas. According to Ramlah et al. (2016), Hapsari and Lestari (2016) Raja Bulu banana's fruit has cylindrical shape, with a slightly thick skin (around 3 mm) and round or square pointed edges. The banana's flesh is yellowish white and has no seeds.

Raja Bulu banana flower blooms at the age of 14 months and the fruit will ripen around 150-160 days or 5 to 5.5 months after flowering (Ramlah et al., 2016). Banana plants are propagated vegetatively; hence, there are limitations in obtaining genetic variation and it requires a long generation time in its vegetative cycle (Masykuroh et al., 2017). A problem in the diversity of bananas is parthenocarpy where the fruits were formed formation without going through the process of fertilization, so that the fruit is seedless. Efforts to improve plant properties can be done through increasing the genetic diversity; one of which is through induced mutation. Induced mutation has a high potential to bring genetic improvement to vegetatively propagated plants (Ghag and Ganapathi, 2017). One of the mutagenic agents often used to induce mutation is gamma ray mutagens (Indrayanti et al., 2012). The use of gamma rays is widely used in mutation breeding because gamma rays are able to interact with atoms or molecules in cells with water to produce free radicals in cells. These radicals can damage or modify important components in plant cells and affect the morphological, anatomic, biochemical and physiological differentiation of plants (Kebeish et al., 2015).

Gamma rays emitted from radioactive isotopes or nuclear reactors is a high-energy electromagnetic beam; when applied to plant tissue, it can change the composition of genes so that the genetic diversity increases in irradiated plants (Maharani et al., 2001; Astutik, 2009; Khumaida et al., 2015). Genetic diversity is very essential on the success of plant breeding. Genetic diversity on plant breeding is when there are variations in the value of genotypes between individuals in the population. Collection of various plant genotypes is an early stage of plant breeding programs and can then be used as a source to get the desired genotypes. The wider genetic diversity of a plant, the greater the opportunity to obtain the desired traits (Sari et al., 2014). The gamma rays had stimulatory effect on yield attributing characters as compared to control. Hence, genetically improved plants for production of high yield attributing characters can be achieved through induced mutation by gamma rays (Verma et al., 2017).

Genetic changes in plants can be seen from the appearance of different plant properties (mutants). Treatments with the right irradiation dose will produce plants that have superior productivity and a shorter harvest age. Treatments of gamma rays have been proven to be more efficient in increasing the genetic variability for traits such as days to flowering and maturity. The isolated mutants possessed desirable plant architecture and took lesser days to flower and mature as compared to parental lines (Goyal et al., 2019). The most appropriate determination of irradiation dose is based on radiosensitivity. Radiosensitivity is a relative measurement that gives a quantitative indication of the effects of radiation from irradiated objects. This can be done by determining a lethal dose of 50% (LD50) which generally results in maximum diversity with a minimum number of unexpected mutants (Indrayanti et al., 2013). This research aimed to perform selection procedures on growth traits on M1V1 generation of Raja Bulu banana (*Musa paradisiaca* Linn.) obtained by gamma rays irradiation. These plants are expected to produce banana varieties with early maturity and high yield. Raja Bulu banana are parthenocarpic in nature which causes limitations in obtaining genetic variation, so research needs to be done to obtain new and superior banana varieties by utilizing this variety.

The utilization of gamma ray irradiation is expected to support sustainable agriculture systems. To be sustainable, agriculture systems must meet the requirements of the present and future generations for its products and services, while ensuring profitability, environmental health and social and economic equity. Irradiation may be an ideal and sophisticated technique to improve the nutritional quality of pulses and its products, while facing the present challenges of maintaining food security and minimizing environmental damage under shifting climate conditions (Takinami et al., 2016).

MATERIALS AND METHOD

The study was conducted from March 2018 to April 2019 in Bakaran Sukosari Village, Jumantono Sub-district, Karanganyar Regency, Central Java, Indonesia. The research location is 7°37'48.3" South Latitude and 110°56'51.2" East Longitude with an altitude of approximately 170 meters above sea level (masl) and has a dryland Alfisol soil type. Daily temperature at the study site ranged from 27-28.5°C and humidity was between 76.1-85.6%. Average rainfall in February to June 2018 was 6-537.5 mm month^{-1}, but in July to August there was no rain. High rainfall occurred in November 2018, which was 180 mm month^{-1}.

Materials used in this study were organic fertilizer, urea fertilizer, SP 36 fertilizer, KCl fertilizer, Raja Bulu banana irradiated gamma ray with doses of 5 Gy, 10 Gy, 15 Gy and without irradiation (control) aged 8 months old, stationery, knife, pits, hoes, buckets, hoses, analytical scales, calipers, name tags, scissors, machetes or knives, sacks, IPGRI (International Plant Genetic Resources Institute) descriptors for banana plants, brushes, digital cameras and hand refractometers.

The study used a randomized complete block design without replication. Qualitative and quantitative data were obtained by observing the generative growth of each Raja Bulu banana plants which were irradiated with gamma rays at a dose of 5 Gy, 10 Gy, 15 Gy and without radiation as a descriptive control. The number of plants used were 34 plants (without irradiation (control) 6 plants, 7 plants with a dose of 5 Gy, 11 plants with a dose of 10 Gy and 10 plants with a dose of 15 Gy.

The research activities included watering, thinning tillers, fertilizing, land sanitation, fruit wrapping, banana heart cutting, pest and disease control and harvesting. The puppy thinning activities are carried out every 3 months for every banana tillers, namely leafy swords and puppies about 20-40 cm tall. Fertilizing the Raja Bulu banana plant was done every 3 months with a dose of 100 g of urea per planting hole, 150 g of SP-36 per planting hole and 450 g of KCL per planting hole. Land sanitation in the form of manual weed control by pulling weeds around the surrounding planting holes and cutting banana leaves that were old and dry. Pest and disease control activities were carried out manually, namely pest control using botanical pesticides at the beginning of flowering and fruit emergence and cutting down banana plants to their roots and dumped away from the land and then buried when attacked by disease, then planting pits of diseased plants were given dolomite. The observation of variables including flowering date, harvesting date, number of fruit combs in one bunch, number of fruits per comb, total weight of fruit in one bunch, comb weight, fruit weight, fruit diameter, fruit skin thickness.

The observational data obtained were analyzed descriptively by boxplot. The growth characteristics of individual plants treated with irradiation doses of 5 Gy, 10 Gy, 15 Gy were compared with plants without irradiation (control) treatment, then presented in table. A boxplot is a graph that gives a good indication of how the values in the data are spread out, they have the advantage of taking up less space, which is useful when comparing distributions between many groups or datasets. An outlier is an observation that is numerically distant from the rest of the data. When reviewing a boxplot, an outlier is defined as a data point that is located outside the fences (“whiskers”) of the boxplot. This method has advantages in order plant breeders to select the superior characters of plants. An outlier can be seen as a superior characters or not depending on the parameters set by the breeders.

RESULTS AND DISCUSSION

Flowering and harvesting date

The results showed that gamma ray irradiation treatment caused mutations towards the positive direction. As seen from the harvest age of Raja Bulu banana irradiation treatment had an earlier harvest age than the control (Table 1). Raja Bulu banana which had an early harvest age was in plant samples 18 and R3 3 with age 311 days after planting (DAP). According to Abdulhafiz et al. (2018) different irradiation doses affected crop harvest time; irradiation in Raja Bulu banana causes harvest time earlier than control, so that harvesting can be up to almost 60 days or 2 months. Samples of plants R3 40, R3 6, R2 99 and R2 16 showed the longest harvest age, which were 626 DAP, 616 DAP, 639 DAP and

616 DAP. The 10 Gy gamma ray irradiation treatment (R2) had the earliest harvest age which was 324 DAP in R2 98 samples. The plant feather plant treatment of 5 Gy gamma ray irradiation had an earlier harvest time than the treatment without irradiated rays gamma (control) i.e. R1 14 has a harvest age of 335 DAP while the control sample R0 33 has a harvest age of 373 DAP, so it was faster 38 DAP or about 1 month from the control plant.

Table 1. Flowering date (DAP) and harvesting date (DAP) of Raja Bulu M1V1

Plant code	Irradiation dose (Gy)	Flowering date (DAP)	Harvesting date (DAP)
R0 9	Control	297	416
R0 12	Control	294	409
R0 27	Control	263	381
R0 33	Control	259	373
R1 4	5 Gy	246	368
R1 6	5 Gy	264	392
R1 9	5 Gy	226	339
R1 14	5 Gy	223	335
R1 35	5 Gy	287	399
R2 6	10 Gy	231	339
R2 7	10 Gy	277	396
R2 16	10 Gy	508	616
R2 17	10 Gy	297	413
R2 19	10 Gy	294	404
R2 35	10 Gy	240	343
R2 97	10 Gy	240	343
R2 98	10 Gy	208	324
R2 99	10 Gy	534	639
R3 2	15 Gy	231	339
R3 3	15 Gy	227	311
R3 6	15 Gy	504	616
R3 9	15 Gy	246	343
R3 18	15 Gy	223	311
R3 20	15 Gy	252	358
R3 28	15 Gy	241	358
R3 34	15 Gy	238	339
R3 40	15 Gy	528	626

According to Due et al. (2019) mutation activities aimed to increase diversity in plant height, age of flowering and age of harvest. The treatment of gamma ray irradiation in plants can produce changes in those properties at a faster harvest age. Age of flowering were related to harvest age of the plant. The faster the flowering age, the faster harvesting time will come. According to Rachmawati et al. (2019) that giving gamma ray irradiation can change the genetic makeup of agronomic traits, one of which is speeding up the time of flowering and harvest age.

Ramakrishna et al. (2018) and Fanindi et al. (2019) stated that gamma rays are the main physical mutagens used to induce genetic variation. The irradiation treatments of 5 Gy, 10 Gy and 15 Gy gave a variety of flowering and harvest age in Raja Bulu banana plants in Table 1. Sample R2 98 irradiation treatment of 10 Gy (R2) had the earliest flowering age compared to other plant samples, i.e. 208 DAP. According to Abdulhafiz et al. (2018) the most appropriate dose of gamma ray irradiation to encourage growth and morphological variation is 10 Gy. The gamma irradiation treatment doses of 5 Gy (R1) and 15 Gy (R3) had the same earliest flowering age, namely 223 DAP in samples R1 14 and R3 18. The gamma ray irradiation treatment in this study made the Raja Bulu bananas have an early maturity of around 1-3 months compared to control plants of around 10-11 months. Dayarani et al. (2014) stated that Raja Bulu banana has a flowering age of 10-11 months (300-330 days). This is also supported by Sales et al. (2013) CEMSA ¾ cultivar banana have a shorter flowering age than controls.

Masruroh et al. (2018) also declared that the doses of gamma irradiation had very significant effect on flowering date. This indicates that mutation has occurred due to radiation exposure of gamma rays, which causes changes in chromosome structure, thus affecting the emerged phenotypes like flowering date.

Total weight of fruit in one bunch and number of fruit combs in a bunch

The results showed that the higher the dose of gamma ray irradiation, the higher the number of combs per bunch (Table 2).

Table 2. Total weight of fruit in one bunch and number of fruit combs in a bunch Raja Bulu banana M1V1

Plant code	Irradiation dose (Gy)	Total weight of fruit in one bunch (kg)	Number of fruit combs in a bunch
R0 9	Control	1.09	3
R0 12	Control	3.58	6
R0 27	Control	1.49	4
R0 33	Control	2.22	4
R1 4	5 Gy	2.97	5
R1 6	5 Gy	2.35	4
R1 9	5 Gy	2.94	5
R1 14	5 Gy	3.31	5
R1 35	5 Gy	2.04	4
R2 6	10 Gy	2.42	5
R2 7	10 Gy	1.71	4
R2 16	10 Gy	1.68	4
R2 17	10 Gy	1.37	5
R2 19	10 Gy	2.19	5
R2 35	10 Gy	2.81	4
R2 97	10 Gy	2.24	4
R2 98	10 Gy	4.40	6
R2 99	10 Gy	2.84	4
R3 2	15 Gy	2.45	5
R3 3	15 Gy	2.25	6
R3 6	15 Gy	2.16	4
R3 9	15 Gy	1.73	5
R3 18	15 Gy	3.11	6
R3 20	15 Gy	1.61	4
R3 28	15 Gy	3.66	5
R3 34	15 Gy	3.34	5
R3 40	15 Gy	1.17	3

According to Qamar et al. (2016) the increasing radiation given to banana plants, the bigger the banana plants showed the difference with the control. The highest number of fruit combs in the 15 Gy irradiation treatment (R3) was in the samples of R3 3 and R3 18 with a total of 6 combs bunch^{-1}, while the least number of combs was in the sample R3 40 with a total of 3 combs bunch^{-1}. Gamma ray irradiation treatment with 10 Gy (R2) had the highest number of combs of 6 combs bunch^{-1} in R2 98 samples, while the least number of combs were 4 combs bunch^{-1} in samples R2 97, R2 35, R2 16 and R2 7. Number highest number of combs was of fruit in a bunch in the 5 Gy (R1) gamma ray irradiation treatment which was 5 combs bunch^{-1}, while the minimum number of combs was 4 combs bunch^{-1}. Raja Bulu banana plants without gamma ray irradiation treatment (control) has the highest number of combs which was 6 combs bunch^{-1} in sample R0 12. The lowest number of combs treated without gamma ray irradiation (control) were 3 combs bunch^{-1} in sample R0 9. Overall there are differences in the number of combs in one bunch per individual plant in the 5 Gy, 10 Gy and 15 Gy gamma ray irradiation treatment with the treatment without gamma ray irradiation (control). According to Rayis and Abdallah (2014) the radiation treatment given can increase plant diversity which is directly proportional to the increase in radiation dose.

Each of the Raja Bulu banana individual in the 10 Gy gamma ray irradiation treatment (R2) showed higher total fruit weight in a single bunch than without irradiation treatment (control) (Table 2). This is supported by Due et al. (2019) that gamma ray irradiation at a dose of 10 Gy showed increases in banana growth in all parameters observed when compared to controls. The highest total weight of fruit in a single bunch was found in 10 Gy gamma ray irradiation treatment, namely R2 98 sample at 4.4 kg; while the lowest total weight of fruit in one bunch was 1.37 kg in sample R2 17. Kemal et al. (2018) states that the most appropriate dose of gamma ray irradiation to encourage growth and morphological variation is a dose of 10 Gy and a dose of 20 Gy. The gamma irradiation dose of 15 Gy (R3) had the highest total weight of fruit in one bunch in R3 28 sample of 3.66 kg; while in sample R3 40 showed the total weight of fruit in one bunch was the lowest at 1.17 kg. Banana Bulu irradiation treatment of 5 Gy (R1) had the highest total weight of fruit in one bunch which was 3.31 kg in sample R1 14; while the total weight of fruit in one bunch was the lowest in sample R1 35 which was 2.04 kg. Raja Bulu banana plant without gamma ray irradiation (control) had the highest total weight of fruit in one bunch which was 3.58 kg in sample R0 12, while the lowest total weight of fruit in one bunch in sample R0 9 was 1.09 kg. Anwarudin et al. (2010) stated that Cobalt-60 gamma ray dose of 15 Gy can cause an increase in bunch weight.

Sushmitharaj et al. (2019) and Khumaida et al. (2015) states that among the irradiation treatment can be creating genetic variability and improvement of phenotypic banana. Phenotypic banana seen Figure 1 plant height was positively correlated with panicle length, panicle weight and productive tillers per plant.

a. b. c. d.

Figure 1. Number of fruit combs in one bunch at control (a); irradiation treatment 5 Gy (b); irradiation treatment 10 Gy (c); and irradiation treatment 15 Gy (d)

Number of fruits each comb, weight of comb and fruit weight

The results of the study on the number of fruits per comb on each individual plant of Raja Bulu banana irradiated by gamma rays from the first comb to the third comb showed variation (Table 3). The results showed that gamma ray irradiation treatments showed the average number of fruits per comb, comb weight and fruit weight had higher yields than controls. According to Datta et al. (2018) induction of mutations using gamma irradiation in banana cultivation can produce new properties as an expression of phenotype. New properties that emerge in each individual irradiated banana plant can produce higher production than plants without irradiation.

Raja Bulu banana with irradiation treatment of 5 Gy (R1) had an average number of fruits per comb ranging from 8 pieces comb^{-1} to 12 pieces comb^{-1}. Raja Bulu banana irradiated by 10 Gy (R2) had an average number of fruits per comb ranging from 6 pieces comb^{-1} to 11.66 pieces comb^{-1}. Raja Bulu banana irradiated by 15 Gy

(R3) had an average number of fruits per comb ranging from 5.33–12.66 pieces comb^{-1}, while controls had an average number of fruits 6.33-10 pieces comb^{-1}. According to Dewi and Dwimahyani (2005) gamma ray irradiation at a dose of 15 Gy in banana plant explants caused changes in plant phenotypes. Changes in the phenotypes of banana plants occurred because of changes in plant genotypes due to mutations at the level of genes that control each of these traits.

Table 3. Number of fruits each comb, weight of comb and fruit weight of Raja Bulu banana M1V1

Plant code	Irradiation dose (Gy)	Number of fruits each comb	Weight of comb (g)	Fruit weight (g)
R0 9	Control	6.33	365.67	58.83
R0 12	Control	9.66	660.67	63.50
R0 27	Control	10.00	433.33	40.00
R0 33	Control	10.00	588.33	56.67
R1 4	5 Gy	9.66	665.00	77.50
R1 6	5 Gy	10.00	580.00	65.83
R1 9	5 Gy	10.00	626.67	74.17
R1 14	5 Gy	12.00	740.00	75.83
R1 35	5 Gy	8.00	538.33	55.67
R2 6	10 Gy	10.33	648.33	70.00
R2 7	10 Gy	10.00	461.67	46.17
R2 16	10 Gy	6.00	450.67	68.67
R2 17	10 Gy	11.66	302.67	30.33
R2 19	10 Gy	10.00	496.00	45.83
R2 35	10 Gy	10.00	763.33	83.33
R2 97	10 Gy	8.00	593.33	81.67
R2 98	10 Gy	11.33	956.67	96.67
R2 99	10 Gy	9.00	737.33	79.17
R3 2	15 Gy	9.00	580.00	74.17
R3 3	15 Gy	12.66	506.67	49.17
R3 6	15 Gy	8.00	654.67	74.67
R3 9	15 Gy	12.33	385.00	45.00
R3 18	15 Gy	10.66	643.33	57.50
R3 20	15 Gy	7.66	440.00	60.00
R3 28	15 Gy	11.00	911.67	82.50
R3 34	15 Gy	11.66	738.33	79.17
R3 40	15 Gy	5.33	389.67	57.00

The 5 Gy, 10 Gy and 15 Gy irradiation treatments affect the comb weight on Raja Bulu banana. The plants treated with irradiation yielded higher comb weight than without irradiation (control) (Table 3). The results of the study individually showed that the irradiation treatment at a dose of 10 Gy (R2) in sample R2 98 (Table 3) had the highest comb weight of 956.67 g; while the 15 Gy irradiation treatment (R3) had a comb weight of 911.67 g. Raja Bulu banana irradiated 5 Gy (R1) treatment had a comb weight of 740 g, while the control in sample R0 12 has a lower comb weight of 660.67 g. Ari Kusuma Putra et al. (2017) stated that in the first generation of plants, namely generation plants, gamma ray irradiation treatment can experience physiological changes, then the chance of genetic changes is obtained which shows more positive nature changes.

Based on the results of the study presented in Table 3, it can be seen that the higher the irradiation dose increase the diversity of fruit weight in each individual. The weight of Raja Bulu banana on irradiation treatment of 10 Gy (R2) and 15 Gy (R3) has a wider variation compared to the controls. This can be seen from the range of the minimum value and maximum value of fruit weight per comb. Gamma ray irradiation doses of 10 Gy and 15 Gy have significant differences with control so that the explants of banana plants have caused changes in plant phenotypes (Dewi and Dwimahyani, 2005; Kemal et al., 2018).

Raja Bulu banana plant treatment irradiation dose of 5 Gy had a fruit weight ranging from 55.67 g to 77.50 g. Raja Bulu banana weight of 10 Gy irradiation treatment were ranged from 30.33 g to 96.67 g and in 15 Gy irradiation treatment the weight were ranged from 45 g to 82.50 g. Gamma ray irradiation treatment produced more fruits than control so that it was followed by increasing the weight of the fruit on each comb and the weight of each comb. Dalfiansyah et al. (2016) stated that the second generation of mutants (M2) produced genotypes with fruit weight that were better than control genotypes or it could be said that there was an improvement in the characteristics of plant fruit weight.

Fruit diameter and fruit skin thickness

Raja Bulu banana fruit with 5 Gy (R1) irradiation treatment in sample R1 4 had thicker fruit skin by 3.10 mm compared to the control sample R0 27 which was relatively thin at 2.62 mm (Table 4).

Table 4. Fruit diameter and fruit skin thickness Raja Bulu banana M1V1

Plant code	Irradiation dose (Gy)	Fruit diameter (cm)	Fruit skin thickness (mm)
R0 9	control	3.13	1.76
R0 12	control	2.92	2.23
R0 27	control	2.63	2.62
R0 33	control	2.93	1.89
R1 4	5 Gy	2.97	3.10
R1 6	5 Gy	2.75	1.54
R1 9	5 Gy	3.10	1.89
R1 14	5 Gy	3.08	2.55
R1 35	5 Gy	2.94	2.17
R2 6	10 Gy	2.76	2.48
R2 7	10 Gy	2.69	2.18
R2 16	10 Gy	3.21	4.13
R2 17	10 Gy	2.31	2.21
R2 19	10 Gy	2.60	2.40
R2 35	10 Gy	3.18	2.82
R2 97	10 Gy	3.26	3.16
R2 98	10 Gy	3.41	3.15
R2 99	10 Gy	3.27	4.13
R3 2	15 Gy	3.03	1.97
R3 3	15 Gy	2.52	2.13
R3 6	15 Gy	3.36	2.51
R3 9	15 Gy	2.13	2.02
R3 18	15 Gy	3.07	2.02
R3 20	15 Gy	2.62	1.63
R3 28	15 Gy	2.67	2.71
R3 34	15 Gy	2.86	2.92
R3 40	15 Gy	2.74	3.15

According to Table 4 fruit skin thickness of Raja Bulu banana peels were 15 Gy (R3) irradiation treatment ranging from 1.63 mm to 3.15 mm. Samples R2 16 and R2 99 had thicker skin than the peels in 5 Gy, 15 Gy irradiation treatments with thickness of 4.13 mm. Banana on irradiation treatment of 10 Gy (R2) on average has a relatively thick banana peel, but there are also some plant samples that have relatively thin fruit peel. This is because gamma ray irradiation exerts a random influence on each individual Raja Bulu banana plant. Masykuroh et al. (2017) and Probojati et al. (2019) states that gamma ray irradiation results in random mutations, because the induction of mutations is carried out in a group of cells or tissue, so that the probability for genetic or epigenetic mutations can be expressed as phenotypic changes become greater.

Table 5. Raja Bulu banana M1V1 selected candidates are the result of gamma ray irradiation

Plant code	Flowering age (DAP)	Harvest age (DAP)	Total weight of fruit in one bunch (kg)	Weight of comb (g)	Fruit weight (g)	Number of fruit combs in a bunch	Number of fruits each comb	Fruit diameter (cm)	Fruit skin thickness (mm)
R1 14	223	335	3.360	410-1245	60-100	5	04-18	2.759-3.253	2.63-2.85
R2 98	208	324	4.400	855-1020	93-105	6	10-12	3.313-3.590	2.97-3.39
R2 6	231	339	2.425	555-7050	65-75	5	10-12	2.418-2.962	2.14-3.04
R3 18	223	311	3.110	615-6850	53-67.5	6	10-11	3.055-3.109	1.96-2.12
R3 34	238	339	3.340	675-7800	73-85	5	11-12	2.810-2.954	2.82-3.04

Rafiuddin et al. (2013) also stated that there was no significant effect of irradiation dose to produce mutants. It happened very randomly. Although the level of gamma irradiation dose was given to the same plant, the effects may not be the same. Reproducing the same protocol on different types of plants would give even more random mutants. The effectiveness of irradiation must be first studied to determine the optimum dose.

Raja Bulu banana plants which were the results of gamma ray irradiation on variable fruit diameter and fruit skin thickness showed high variation. This is because gamma ray irradiation can change components in the cell. Kebeish et al. (2015) states that gamma rays are able to interact with atoms or molecules in cells with water to produce free radicals in cells. These radicals can damage or modify important components in plant cells and affect the morphological, anatomic, biochemical and physiological differentiation of plants.

Gamma ray irradiation treatment showed an influence on the diameter of Raja Bulu banana in Table 3. According to Rosmala et al. (2015) and Al-Mousa et al. (2016) gamma ray irradiation produces free radicals that damage and affect plant morphology, anatomy and biochemistry. Changes in plant morphology and growth are proven by variations in fruits' diameter. The average diameter of Raja Bulu banana individually in the 5 Gy (R1) irradiation treatment ranged from 2.75 cm to 3.10 cm. The diameter of Raja Bulu banana in the 10 Gy (R2) irradiation treatment ranged from 2.31 cm to 3.41 cm, while the diameter of the 15 Gy (R3) irradiation treatment ranged from 2.13 cm to 3.36 cm.

Determination of Raja Bulu banana M1V1 generation selected plants

Plant selection in this study was carried out by selecting the Raja Bulu banana plant M1V1 generation resulting from gamma ray irradiation where the criteria for selection were flowering age and early maturity and high yield of bananas compared to control. Based on the selection of Raja Bulu banana generation M1V1 in Table 5 it is known that there are 5 selected plant candidates from the whole plant sample. Each candidate has superior criteria compared to the control (i.e. samples R1 14, R2 98, R2 6, R3 18, R3 34). The plant samples were chosen for their superior criteria compared to control, namely the age of flowering and early age of harvest and has a high yield. According to Romadhon et al. (2018) genotypes with earlier flowering time will usually be able to be harvested faster. Early maturing plants are very attractive to farmers and usually the plants that flower faster will bear fruit faster.

Majeed et al. (2018) states that gamma irradiation provides a feasible choice to plant breeders for bringing desired traits concerned with better germination and plants' growth; thus avoiding high throughputs of time, labor and cost generally related with selective breeding methods. Since these traits are controlled by genes, positive fluctuation in genomic structure of plants of interest by exposure to gamma irradiation can enhance their germination and general growth characters.

CONCLUSIONS

Gamma ray irradiation on a dose of 10 Gy affects the occurrence of morphological diversity in the generative phase of Raja Bulu banana M1V1 generation. Gamma ray irradiation treatment resulted in 5 individual Raja Bulu banana plants which had the advantage of flowering and harvest age characteristics more quickly than the control ie M1V1 R1 14, M1V1 R2 98, M1V1 R2 6, M1V1 R3 18, M1V1 R3 34. This study is a preliminary study to test and select the genetic variance of bananas through mutation breeding. Further research is needed to determine the inheritance of early age maturity characters in the generations of offspring.

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