Gamma irradiation on generative growth of Raja Bulu banana (*Musa paradisiaca* L.) MV1

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Abstract. *Musa paradisiaca* L. or Raja Bulu banana are climate change-resistant plants, characterized by the ability of the stem to store water hence it can survive under drought conditions. Leaf size is wide and long and a large number then the banana leaf is a provider of oxygen through photosynthesis for human health. One of the weaknesses of Raja Bulu plantain is its long harvest live which is between 12-15 months making it less effective to meet market demand. The efforts to get a banana plant with superior quality can be improved the varieties through plant breeding programs using gamma-ray irradiation. Raja Bulu banana has been acclimatized to the land as the first generation (MV1). This research is an attempt to obtain short-lived banana cultivars in order to provide faster harvest time and increase the population of banana plants as a food source and a source of oxygen for human health. Early maturity of the harvest is one way of avoiding changes in the dry season. The results showed that the Raja Bulu banana with irradiation treatment 20 Gy, 25 Gy, and 20 Gy provide a diversity of character growth on the generative phase compared with Raja Bulu banana without irradiation treatment. Raja Bulu banana with irradiation treatment dose 20 Gy in sample R4 28 become individual selected that has character early maturity harvest 343 DAP (Days After Planting).

1. Introduction

*Musa paradisiaca* L. or Raja Bulu banana is the superior banana variety that has been released by the government. Raja Bulu banana is very popular in the community as a fruit that is consumed fresh because it tastes sweet and delicious besides this banana is also used in a wedding party. The price of these bananas is the highest among other types of bananas. Raja Bulu banana is one type of horticultural plants that are resistant to climate change characterized by the ability of the stem to store water then the banana plants can survive in drought conditions. Leaf size is wide and long and a large number then the banana leaf is a provider of oxygen through photosynthesis for human health. One of the weaknesses of Raja Bulu plantain is its long harvest live which is between 12-15 months making it less effective to meet market demand.

Increased productivity of Raja Bulu banana can be achieved if available seeds which have superior quality. Efforts to get banana plants of superior quality can be improved varieties through plant breeding programs. The technique can be used to obtain high yielding varieties is by mutation induction using mutagenic substances such as gamma rays. Mutations irradiation technique was more advantageous because it can improve one or two properties of plants and can give rise to new properties [1]. This research is an attempt to obtain early harvest age banana cultivars in order to provide faster...
harvest time and increase the population of banana plants as a food source and a source of oxygen for human health. Early maturity of the harvest is one way of avoiding changes in the dry season.

2. Research methods
The research was conducted in March 2018 until April 2019 in the Hamlet of Bakaran, Village Sukosari, District Jumantono, Karanganyar, Central Java. Tools used include calipers, analytical balance, and International Plant Genetic Resource Institute (IPGRI) descriptors. The materials used are potassium chloride fertilizer, Urea, SP-36 fertilizer, organic fertilizer, and plant bananas 8 months old Raja Bulu banana without irradiation treatment as a control (R0) and Raja Bulu banana plants result in gamma-ray irradiation dose of 20 Gy (R4), 25 Gy (R5), 30 Gy (R6). Raja Bulu banana studied is the result of plantlets that have been irradiated with gamma-ray irradiation and acclimatized in the screen house approximately 3 months. Raja Bulu banana was already acclimatized moved to land that has been prepared for the first generation (MV1).

This research is attempt to test the result of gamma-ray irradiation treatment dose of 20 Gy, 25 Gy, 30 Gy and without irradiation as control of each individual plant which aims to determine the characteristics of generative growth of Raja Bulu banana MV1 and obtain candidate selected individual Raja Bulu banana plants MV1 which has advantage of flowering age and early harvest time.

The number of plants each of 4 plants (control), 6 plants (20 Gy), 3 plants (25 Gy), and 1 plant (30 Gy). Variable observation is flowering age, harvest time, total weight of fruit in the bunch, number of hands, number of fruits, hand weight in the bunch, fruit weight, fruit diameter, fruit peel thickness. The results were analyzed using descriptive analysis by observing the growth characteristics of the individual plants were treated with an irradiation dose of 20 Gy, 25 Gy, 30 Gy and compared with plants without irradiation treatment (control), then presented in tabular form.

3. Result and discussion
Gamma-ray irradiation treatment causing mutations in the positive direction as the diversity of flowering date and harvest time besides high dose irradiation causes the power to grow plants to decrease. Irradiation dose 30 Gy giving effect banana plant growth in the in vitro [2]. The results showed that a gamma-ray irradiation treatment dose of 20 Gy, 25 Gy, and 30 Gy provide diversity to the date of flowering and harvesting of Raja Bulu banana (Table 1).

| Plant code | Irradiation dose (Gy) | Flowering age (DAP) | Harvest time (DAP) |
|------------|-----------------------|---------------------|--------------------|
| R0 09      | Control               | 297                 | 416                |
| R0 12      | Control               | 294                 | 378                |
| R0 27      | Control               | 261                 | 381                |
| R0 33      | Control               | 261                 | 374                |
| R4 15      | 20 Gy                 | 240                 | 345                |
| R4 28      | 20 Gy                 | 236                 | 343                |
| R4 31      | 20 Gy                 | 436                 | 575                |
| R4 32      | 20 Gy                 | 297                 | 428                |
| R4 33      | 20 Gy                 | 308                 | 428                |
| R4 46      | 20 Gy                 | 343                 | 479                |
| R5 04      | 25 Gy                 | 505                 | 637                |
| R5 05      | 25 Gy                 | 345                 | 479                |
| R5 10      | 25 Gy                 | 498                 | 614                |
| R6 09      | 30 Gy                 | 354                 | *                  |

DAP = Days After Planting, *: dead plant

Gamma-ray irradiation treatment dose 20 Gy (R4) has a flowering age ranged from 236 days after planting (DAP) to 436 days after planting (DAP) (Table 1). Individually Raja Bulu banana plants with
20 Gy (R4) irradiation treatment on a sample of R4 28 plants flower earlier which is 236 days after planting (DAP). Raja Bulu banana plants by irradiation of 25 Gy (R5) has the longest flowering date that is 345 days after planting (DAP) until 505 days after planting (DAP). Raja Bulu banana plant with gamma-ray irradiation treatment dose 30 Gy (R6) has a longer flowering date if compare Raja Bulu banana plants without gamma-ray irradiation treatment (control) that is 354 days after planting (DAP). The gamma-ray irradiation treatment dose of 20 Gy (R4) causes the mutant Raja Bulu banana plants into early duration. This suggests that the mutation in the positive direction because there are some plants that experienced a flowering of early maturing age so as to accelerate harvesting.

Total weight of fruit in the bunch highest at 20 Gy (R4) irradiation treatment of 2.87 kg at R4 31 plant samples, while the total weight of the fruit in the bunch low of 1.04 kg in plant samples R4 15. Total weight of fruit in the bunch highest of 25 Gy (R5) irradiation treatment of 1.90 kg at plant samples R5 4 and lowest weight of 1.10 kg at plant sample R5 10. Raja Bulu banana plants without irradiation treatment (control) had a total weight of fruit in the bunch ranged from 1.10 kg to 3.58 kg (Table 2). The irradiated plants tend to be shorter than plants without irradiation [6].

**Table 2. Hands weight on the bunch, and total weight fruit on the bunch Raja Bulu banana MV1**

| Plant code | Irradiation dose (Gy) | Hands weight in the bunch (g) | Total weight fruit in the bunch (kg) |
|------------|-----------------------|-----------------------------|----------------------------------|
| R0 09      | Control               | 369                         | 1.10                             |
| R0 12      | Control               | 661                         | 3.58                             |
| R0 27      | Control               | 433                         | 1.49                             |
| R0 33      | Control               | 588                         | 2.22                             |
| R4 15      | 20 Gy                 | 348                         | 1.04                             |
| R4 28      | 20 Gy                 | 405                         | 1.77                             |
| R4 31      | 20 Gy                 | 557                         | 2.87                             |
| R4 32      | 20 Gy                 | 407                         | 1.59                             |
| R4 33      | 20 Gy                 | 384                         | 1.59                             |
| R4 46      | 20 Gy                 | 326                         | 1.24                             |
| R5 04      | 25 Gy                 | 483                         | 1.90                             |
| R5 05      | 25 Gy                 | 354                         | 1.38                             |
| R5 10      | 25 Gy                 | 368                         | 1.10                             |

Number of hands Raja Bulu banana with gamma-ray irradiation treatment dose 20 Gy (R4) ranging from 3 to 5 hands, while in the 25 Gy (R5) gamma-ray irradiation treatment has a number of hands ranged from 3 to 4 hands. The number of hands-on Raja Bulu banana plants without gamma-ray irradiation treatment (control) ranged from 3 to 6 hands (Table 3). Raja Bulu banana 20 Gy (R4) gamma-ray irradiation treatment in plant samples R4 28 and R4 31 has the highest number there are 5 hands. Raja Bulu banana without gamma-ray irradiation treatment (control) samples R0 12 has the highest number of hands there are 6 hands (Table 3).

The number of hands and the number of fruits determine the number of banana production in each plant. Overall the number of hands each individual plant in all treatments is not much different from the Raja Bulu banana plants without gamma-ray irradiation treatment (control). Raja Bulu banana plants will flourish and can produce large bunches on the environment has sufficient water availability. Banana crop cultivation activities are not only determined by the level of soil fertility and cultivation techniques are applied. Climate change is also a major impact on the growth of banana plants [7].

The number of fruits at each individual Raja Bulu banana plant varies greatly. The results showed that Raja Bulu banana irradiated with 20 Gy (R4) has a number of fruits per individual ranged hand every 7 pieces/hands up to 10 pieces/hands. Raja Bulu banana 25 Gy (R5) irradiation results have a number of fruits ranging from 5.67 pieces/hands up to 10.67 pieces/hands. Raja Bulu banana plant irradiated 20 Gy (R4) on samples R4 31 and R4 28 has the number of fruit on each hand more, whereas in the samples R4 15 has a number of pieces there every hand fewer than individual plants on irradiated
20 Gy (R4). Total fruit of Raja Bulu banana in the hands at 25 Gy (R5) irradiation treatment sample R5 has a number of pieces of each hand higher when compared with 20 Gy (R4) irradiation treatment.

Based on observations are presented in table 3 shows that the higher the dose of a given weight of the fruit can increase the diversity of each individual. Heavy pieces of Raja Bulu banana at 25 Gy (R5) irradiation treatment has a greater diversity compared with 20 Gy (R4) irradiation treatment. It can be seen the range of minimum and maximum value of the average weight of the fruit hand. Induction of mutation using gamma rays can increase the genetic diversity of the first generation of plants [8].

### Table 3. Number of hands, number of fruits, fruit weight Raja Bulu banana MV1

| Plant code | Irradiation code (Gy) | Number of hands | Number of fruits | Fruit weight (g) |
|------------|------------------------|----------------|-----------------|-----------------|
| R0 09      | Control                | 3              | 6.33            | 58.8            |
| R0 12      | Control                | 6              | 9.67            | 63.5            |
| R0 27      | Control                | 4              | 10.00           | 40.0            |
| R0 33      | Control                | 4              | 10.00           | 56.7            |
| R4 15      | 20 Gy                  | 3              | 7.00            | 51.3            |
| R4 28      | 20 Gy                  | 5              | 9.67            | 44.2            |
| R4 31      | 20 Gy                  | 5              | 10.00           | 54.7            |
| R4 32      | 20 Gy                  | 4              | 8.67            | 46.2            |
| R4 33      | 20 Gy                  | 4              | 9.33            | 36.5            |
| R4 46      | 20 Gy                  | 4              | 9.33            | 34.2            |
| R5 04      | 25 Gy                  | 4              | 10.67           | 44.0            |
| R5 05      | 25 Gy                  | 4              | 9.67            | 39.5            |
| R5 10      | 25 Gy                  | 3              | 5.67            | 67.0            |

Raja Bulu banana dose of 20 Gy irradiation treatment has a fruit weight ranging from 34.2 g to 54.7 g. Raja Bulu banana dose irradiation 25 Gy treatment ranged from 39.5 g to 67 g. Gamma-ray irradiation treatment despite producing fruit each hand amount more than controls but not followed by increasing the weight of the fruit on each hand. Bananas are formed on irradiation treatment and are less likely to contain or have a smaller fruit size.

### Table 4. Diameter and fruit peel thickness of Raja Bulu banana MV1

| Plant code | Irradiation dose (Gy) | Diameter fruit (cm) | Fruit peel thickness (mm) |
|------------|------------------------|---------------------|--------------------------|
| R0 09      | Control                | 3.12                | 2.26                     |
| R0 12      | Control                | 2.91                | 2.32                     |
| R0 27      | Control                | 2.62                | 2.62                     |
| R0 33      | Control                | 2.92                | 2.39                     |
| R4 15      | 20 Gy                  | 2.96                | 3.08                     |
| R4 28      | 20 Gy                  | 2.81                | 2.07                     |
| R4 31      | 20 Gy                  | 313                 | 1.19                     |
| R4 32      | 20 Gy                  | 2.95                | 1.52                     |
| R4 33      | 20 Gy                  | 2.71                | 0.18                     |
| R4 46      | 20 Gy                  | 2.66                | 2.15                     |
| R5 04      | 25 Gy                  | 3.30                | 2.28                     |
| R5 05      | 25 Gy                  | 3.74                | 2.17                     |
| R5 10      | 25 Gy                  | 3.24                | 2.41                     |

Gamma-ray irradiation treatment dose 20 Gy (R4) shows the influence of the diameter fruit Raja Bulu banana on each individual based on the result of descriptive analysis (Table 4). Raja Bulu banana fruit with irradiation treatment, in general, has a diameter lower than the control. The average diameter of the fruit Raja Bulu banana individual at 20 Gy (R4) irradiation treatment ranges from 2.66 cm to
3.13 cm, while the diameter of the Raja Bulu banana individually at 25 Gy (R5) irradiation treatment ranging from 2.74 cm to 3.0 cm. Gamma-ray irradiation can affect the size of a banana one of which can be seen in the size of the diameter of a banana. Gamma-ray irradiation may damage or modify an important component in plant cells and cause changes in some of the morphology, anatomy, biochemistry, and physiology of plants [9].

Raja Bulu banana fruit irradiated dose 20 Gy (R4) on samples R4 33 has a relatively thin fruit peel that is 0.18 mm. Plant sample R4 15 has a fruit peel thicker compared with 25 Gy (R5) irradiation treatment that is 3.08 mm. Raja Bulu banana at 20 Gy (R4) irradiation treatment on average have thin peel fruit, but there are also some samples of plants that have a thick fruit peel. This is because the irradiation is given effect which is random in each individual plant. Mutations occur spontaneously and randomly so as to create a variety of plants [10].

The result of correlation analysis (Table 5) shows that variable flowering age positively correlated with harvesting Raja Bulu banana, but did not correlate with the total weight of the fruit in the bunch, number of hands, number of fruits, weight fruit, weight hands, and fruit peel thickness. The life of flowering plants growing early maturing then harvesting also increasingly early maturity [3]. Raja Bulu banana on plant samples R4 28 and R4 15 with 20 Gy (R4) irradiation treatment has the fastest time of harvest is at the age of 343 days after planting (DAP) and 345 days after planting (DAP). The longest harvesting Raja Bulu banana plants at 20 Gy (R4) irradiation treatment is 575 days after planting (DAP). Raja Bulu banana plants at 25 Gy (R5) irradiation treatment individually have a longer harvest time compared to plants without irradiation (control) and 20 Gy (R4) irradiation treatment. Raja Bulu banana plant samples R5 5 at harvest time had the longest is 637 days after planting (DAP). According to correlation analysis (Table 5) that diameter fruit and highly significant positive correlated with fruit weight, fruit diameter size mean increase also followed by weight gain fruit in the hands, besides the fruit diameter also positively correlated with harvest time.

Table 5. The correlation coefficient between research variables of Raja Bulu banana MV1

| Variable | FA | HT | TWFB | NH | NF | WB | WH | FD | FPT |
|----------|----|----|------|----|----|----|----|----|-----|
| FA       |    |    |      |    |    |    |    |    | 1    |
| HT       | 0.99** | 1  |      |    |    |    |    |    |     |
| TWFB     | 0.04 | -0.01 | 1   |    |    |    |    |    |     |
| NH       | -0.11 | -0.14 | 0.87** | 1 |    |    |    |    |     |
| NF       | -0.05 | -0.01 | 0.55 | 0.68** | 1 |    |    |    |     |
| WB       | 0.23 | 0.16 | 0.52 | 0.18 | -0.00 | 1 |    |    |     |
| WH       | 0.24 | 0.19 | 0.83** | 0.60* | 0.56* | 0.76** | 1 |    |     |
| FD       | 0.65* | 0.60* | 0.08 | -0.23 | -0.36 | 0.75** | 0.38 | 1 |     |
| FPT      | -0.17 | -0.21 | -0.29 | -0.35 | -0.29 | 0.22 | -0.06 | 0.12 | 1    |

Description: ** = significant correlation at the level of 1%. * = significant correlation at the level of 5%. FA= Flowering age, HT= Harvest time, TWFB= Total weight of fruit in the bunch, NH= Number of hands, NF= Number of fruits, WB= Weight fruit, WH= Weight hand, FD= Fruit diameter, FPT= Fruit peel thickness

Hand weight on the bunch is positively correlated with fruit weight and the number of fruit on the hands, means increasing hand weight in the bunch influenced by the weight of fruit in the hands also bigger and increase the number of fruits in the hand (Table 3). The number of fruits and very real positively correlated with the number of hands, which means an increase in the number of pieces in a hand followed by an increase in the number of hands in the bunch. hand weight and the number of hands in the bunch is positively correlated with the total weight of fruit in the bunch, this means increasing of hand weight and the number of hands followed by the total weight gain fruit in the bunch. Raja Bulu banana plants with 25 Gy (R5) irradiation treatment most likely to die. Raja Bulu banana plant on the treatment dose of 30 Gy (R6) can not be made further observations caused plants to die after flowers appeared. This is because of the high irradiation dose treatment so that the process becomes inhibited growth that ended in the death of the plant. Abdulhafiz et al. (2018) explain in his
research that the irradiation dose of 30 Gy in banana plants growing power down the plant. Gamma-ray irradiation dose on Raja Bulu banana only ranges up to 10 Gy, when the irradiation dose is given the higher will inhibit plant growth [4]. Irradiated 20 Gy and 30 Gy were effected hand weight in the bunch becomes lower. Irradiated at a higher dose 25 Gy (R5) affected hand weight in the bunch and total weight of fruit in the bunch to be lower compared with the treatment of 20 Gy (R4) and Raja Bulu banana without irradiation treatment (control). The total weight of the fruit in the bunch each individual plant at 20 Gy irradiation treatment (R4) tend to be lower than the control treatment. The higher dose of irradiation is given affect the weight of the fruit produced in the bunch (Table 2). The results of individual observations show that the weight of the hand each bunch at 20 Gy (R4) irradiation treatment on the first to the third hand lower than those without irradiation treatment (control). The irradiation treatment dose of 25 Gy (R5) provides higher diversity to the weight of the hand in the bunch compared with a dose of 20 Gy (R4) irradiation treatment. The fruit is produced on each hand treatment irradiation 20 Gy (R4) and 25 Gy (R5) is smaller than without irradiation treatment (control) and therefore contributes to the weight of the hand at each Raja Bulu banana. Gamma-ray irradiation treatment causing the degradation of chlorophyll in the leaves. Gamma-ray irradiation at high doses is able to influence the process of leaf photosynthesis [5]. Food substances are formed from the leaf photosynthesis can not compensate for the number of pieces that need to process fruit development disrupted.

3.1. Determination of selected Raja Bulu banana plants generation MV1

Plant selection in the research was conducted by selecting the Raja Bulu banana generation MV1 gamma-ray irradiation results which have superior characteristics such as flowering age and harvesting of early maturing and other superior properties generative phase. Based on the result of observations in the generative phase obtained two plant candidates who have superior properties compared to the control plants, the samples are R4 28 and R4 15. The result of the comparison between each candidate indicates that the sample R4 28 and R4 15 has the character of days to flowering and harvesting of early maturing, but the sample R4 28 has the character of flowering date early that is 236 DAP and harvesting 343 DAP. R4 28 plant samples also showed superior criteria derived from the results of irradiation compared to other samples. Sample R4 28 has a size smaller pieces so it's easy to be consumed in one meal, as well as the amount of fruit produced more in each of his hands. Excellence in samples R4 28 makes the strongest candidate for the result of the selection that will be examined on further MV2 generation.

4. Conclusion

Plant breeding through gamma-ray irradiation at a dose of 20 Gy, 25 Gy, and 30 Gy resulted in the growth of diverse Raja Bulu banana on the generative phase compared to the control treatment. Gamma-ray irradiation treatment dose of 20 Gy in plant samples R4 28 has a flowering early maturing that is 236 DAP, harvest time 343 DAP with a total weight of fruit in the bunch 1.77 kg, number of hands 5, the number of fruits 9-10 fruit, hand weight in the bunch 400-415 g, hand weight 40 to 47.5 g, fruit diameter of 2.77 cm to 2.85 cm, and fruit peel thickness 1.58 mm-2.47 mm.

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