Determine the effect of gamma irradiation towards the growth of two local garlic genotypes

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Abstract. Garlic is a diploid plant that is propagated clonal or vegetatively so that the variability is low. Garlic breeding is limited to the selection of genetic varieties. Genetic diversity in garlic can be increased through mutation breeding. The study used Randomized Complete Block Design [RCBD] with the first factor being the two levels of genotypes [Tawangmangu Baru and Lumbu Kuning] and the second-factor is gamma-ray irradiation dose consisting of 7 level doses [0, 1, 2, 3, 4, 6,8, and 10 Gy]. 14 treatments were groups 4 times and each experimental unit was planted 20 cloves. The cloves were irradiated according to the dosage of gamma rays in PAIR BATAN. The results showed there was a difference in the growth response of each genotype to gamma rays irradiation treatment. The greater the gamma rays irradiation applied the more it suppresses the growth of plant height, plant weight, bulb diameter, bulbil formation and decreases the living percentage of two local garlic genotypes. Gamma rays irradiation dose up to 2 Gy could increase bulb diameter in the 2 local garlic genotypes. Lumbu Kuning was significantly better growth response than Tawangmangu Baru at the same irradiation dose. The radiosensitivity of garlic genotype to gamma rays irradiation was different. Tawangmangu Baru was more sensitive than Lumbu Kuning. LD50 genotype Tawangmangu Baru was obtained at a dose of 7.5 Gy, LD50 Lumbu Kuning at a dose of 10 Gy.

1. Introduction
Garlic is the second most important spice in Indonesia after shallots. Garlic is recognized as a spice for food [1, 7, 13]. Garlic contains an amino acid commonly called "Allin" which is the main chemical element in garlic that is antiseptic [21, 7]. Garlic is believed to be a cure for various diseases [16, 7]. In addition to medicine and food seasonings, garlic extract can be used as an insecticide, fungicide, and bactericide [4, 17, 24, 7].

Garlic is a diploid plant [2n = 2x = 16] which is cloned or vegetatively propagated so that the variability is low. Garlic breeding is limited to the selection of preexisting genetic variability [2, 8, 10]. Genetic diversity in garlic can be increased through mutation breeding [18, 20]. The improvement of garlic varieties using artificial mutation techniques was suggested by [14, 20].

The use of gamma rays is reported to have a positive effect on plants. As reported by [9]. Gamma rays are used to improve biotic stresses, abiotic stresses, and characters both in plants produced from seeds and those propagated vegetatively. Besides, gamma-ray mutations can also improve the character of plant growth and production [23, 25, 15]. The purpose of this study was to determine the effect of two local Indonesia garlic genotypes growth on gamma-rays in MV1 generation.
2. Materials and methods

The study was conducted in the village of Pasir Sarongge, Cianjur Regency, from May to October 2018. Gamma-ray irradiation was carried out at the Isotope and Radiation Application Center of the National Nuclear Energy Agency [PAIR BATAN], Friday market, Jakarta. Garlic genotypes used are Tawangmangu Baru and Lumbu Kuning. Clove as a Planting material irradiated using Gamma rays with a single technique [acute irradiation]. This experiment used a Randomized Complete Block Design. The main plot was genotype which consists of 2 levels, namely [Lumbu Kuning and Tawangmangu Baru]. We used this genotype because this genotype is expected to hold on the middle plains. The subplot is a single dose of irradiation consisting of 7 levels, namely: 0, 1, 2, 4, 6, 8, and 10 Gy. Each treatment combination repeated 4 times. Each experimental unit uses 20 plants. To determine the effect of treatment, the data obtained were analyzed by analysis of variance and if there was an effect of treatment, further tests were performed with the Tukey test at level α=5%.

Cloves are planted on land that has been covered with mulch with a spacing of 15x10 cm. The area of the plot is 4.5 m2. NPK fertilizer was given 3 days before planting in the field, then Phonska was given at 30 DAP, and ZA was given 3 times at 15, 30, and 45 DAP. The dosages of each fertilizer were: ZA 475 Kg / Ha, Phonska 180 Kg / Ha and NPK pearl 200 kg / Ha. Fertilizer is applied straightforwardly.

Observations were made on quantitative characters consisting of Plant height [cm], which is observed from the first week after transplanting until entering the generative phase [measured from above ground to the longest leaf tip]. The number of planted leaves, observed from the first week after transplanting until entering the generative phase [counted the number of green and yellowed leaves]. Age of harvest [HST], is observed when the plant has entered the harvest period. Bulb weight [g], is observed at each crop harvest. Bulb diameter, observed after harvest. Percentage of bulbil formation and single clove formation, observed after harvest.

3. Results and Discussion

The irradiation treatment had influenced the growth of garlic. The greater the dose presented, the more pressed plant growth and reduced the percentage of life garlic plants. Exposure to plants with high doses of gamma-ray irradiation would kill mutated or sterilized material. Whereas the application of gamma-ray irradiation at low doses was able to maintain the viability of plants [5, 3, 19].

3.1. Plant Height

The genotype treatment and irradiation dose gave a very significant effect on plant height parameter. The highest average plant height was found in the control treatment [0 Gy] and the lowest average plant height was found at a dose of 10 Gy [Figure 1]. The influence of genotypes showed that Lumbu Kuning had a higher plant height average than the Tawangmangu Baru genotype. These results indicated that the radiosensitivity of each genotype was different from gamma-ray irradiation. Tawangmangu Baru was more sensitive to exposure to gamma-ray irradiation so that plant height was more inhibited than Lumbu Kuning.

The highest plants were in control plants. This showed that the higher the irradiation dose, the plant height would decrease. This happened because the plant metabolism is disturbed. Irradiation could disrupt protein synthesis that played a role in plant growth [6].

The results section should highlight the crucial foundation of the research and its significance in the context of other previously published works. Results should be written in the past tense and directly. The discussion section should elaborate on the justification of the results by comparing the results obtained from the manuscript and results from previous works. The discussion should not repeat or re-express the mentioned results in the form of sentences.
3.2. Bulb Diameter

The genotype and irradiation dose gave a very significant effect on the diameter of the garlic bulb diameter. The largest bulb diameter was at a dose of 2 Gy and the smallest tuber diameter was at a dose of 10 Gy. A decrease in the size of the garlic bulb diameter occurs at doses of 4-10 Gy [Table 1]. The Lumbu Kuning genotype had a larger diameter than the Tawangmangu Baru genotype [Table 2]. Gamma-ray irradiation treatment affected the size of the garlic bulb diameter, 2 Gy irradiation dose was a dose that was able to stimulate the diameter of the bulbs of garlic. The formation of bulb and cloves in garlic plants required low temperatures and significant temperature differences day and night [13]. Based on the experiments carried out it was suspected that higher irradiation for garlic would inhibit the process of division and elongation of clove cells so that the bulbs did not enlarge.

| Irradiation Dose [Gy] | 0   | 1   | 2   | 4   | 6   | 8   | 10  |
|-----------------------|-----|-----|-----|-----|-----|-----|-----|
| Bulb Diameter [cm]    | 4.22a | 4.13ab | 4.223a | 3.83ab | 3.37bc | 2.98c | 2.11d |

Table 2. Effect of garlic genotype on plant height and bulb diameter

| Garlic Genotype       | Tawangmangu Baru | Lumbu Kuning |
|-----------------------|------------------|-------------|
| Bulb Diameter [cm]    | 3.042b           | 4.067a      |
| Plant height [cm]     | 39.28b           | 52.00a      |

3.3. Plant Fresh Weight

Garlic plant fresh weight did not affect by genotypes and irradiation dose. The heaviest plant weights found at an irradiation dose of 1 Gy and the lightest fresh weight was at a dose of 10 Gy [Figure 2]. Plants with radiation treatment of 1 Gy had more bulbil [Figure 3], so they could increase the fresh weight of the garlic plant.
3.4. Percentage Of Bulbil Formation

The highest percentage of bulbil formation in Tawangmangu Baru genotype was at 4 Gy and in Lumbu Kuning genotype there was at 1 Gy. Bulbil is a rounded organ that is part of the vegetative reproduction of plants. Bulbil contained food reserves resulted from plant photosynthesis translocation. Bulbil garlic would then turn into a segment commonly called cloves [21]. Bulbil or often referred to as air tubers was a failure of flower formation caused by temperature factors [11].

Bulbil in garlic cultivation was an unexpected organ. The formation and development of bulbil on the pseudostem of garlic would divert the assimilate that should be transported to the cloves so that it could result in a smaller bulb during harvest. Based on these results gamma rays irradiation provides an opportunity to suppress the formation of bulb whose dosage varies depending on the genotype of garlic.

3.5. Radiosensitivity and Lethal Dose

Based on observations on plant height parameters, fresh weight, bulb diameter, percentage of bulbil formation, it showed that the Tawangmangu Baru genotype was more sensitive than the Lumbu Kuning to exposure to gamma-ray irradiation. This showed that radiosensitivity also depends on the genotype used. It suggested with high radiosensitivity would increase the percentage of mutants formed, because with a low dose of irradiation has been able to reach more than 50% mortality. Based on the calculation of the live percentage of Tawangmangu Baru and Lumbu Kuning in the gamma-ray irradiation dose tested with, LD50 values were obtained for Tawangmangu Baru at a dose of 7.5 Gy
Different LD 50 values also indicated that the radiosensitivity of the Lumbu Kuning genotype was lower or less sensitive than Tawangmangu Baru for exposure to gamma-ray irradiation. It was suggested that the Tawangmangu Baru genotype is a newly released garlic genotype that was not yet stable, had more water content in the cloves so that more sources of H² ions were irradiated, skin thickness of the clove was thinner, and the Lumbu Kuning could adapt to lower land heights so that it was more resistant to high-temperature stress [900 meters above sea level].

4. Conclusion
Genotype and doses of gamma rays irradiation gave a significantly different response to bulb diameter, and plant height, but did not give significant effect to the number of leaves and plant fresh weight. Irradiation dose at 2 Gy could increase vegetative growth on the Lumbu Kuning garlic genotype and gave high bulb diameter and plant fresh weight. Lumbu Kuning genotype gave 100 percent normal bulb with cloves compared to Tawangmangu Baru 97 percent. Highest Bulbil formation in Lumbu Kuning obtained on dose 1 Gy while Tawangmangu Baru at dose 4 Gy. Tawangmangu Baru more sensitive to gamma rays irradiation compares to Lumbu Kuning. LD50 value Tawangmangu Baru genotype obtained at dose 7.5 Gy, and LD50 Lumbu Kuning at dose 10 Gy.
References

[1] Ackermann RT, Mulrow CD, Ramirez G, Gardner CD, Morbidoni L, Lawrene, VA 2001 Garlic shows promise for improving some cardiovascular risk factors. Arch. Intern Med. 161 813-824

[2] Ahloowalia BS, Maluszynski M 2001 Induced mutations a new paradigm in plant breeding. Euphytica. 118 167-173

[3] Bhatnagar, PS and SP Tiwari 1991 Soybean improvement through mutation breeding in India Vol. I. IAEA 381-391

[4] Borukh IF 1975 Differential mutagenic sensitivity of three varieties of Allium cepa L. Pis chereraya Teknologiya. 1 21-23

[5] Broertjs C 1982 Interessante ontuirle kilingen in sortiment Streptocarpus. Valkbl. Bloe-mistry 10 36-37

[6] Casarett AP 1968 Radiation Biology. Prentice Hall, Inc. Englewood Cliffs. New Jersey

[7] Chetna 2017 Induction of mutation through physical and chemical mutagens and characterization of mutant lines in garlic (Allium sativum L.). (thesis). Raipur (INDIA) Indira Gandhi Krishi Vishwavidyalaya

[8] Goyal S, Khan S 2010 Induced mutagenesis in plants by ionizing radiations. Brookhaven Sym. Biol. 6 252-279

[9] Jain SM 2010 Induction of Mutations in Fruits of Tropical and Subtropical Regions. AbstrInt.Sym.Trop.Subtrop.Fruit.Crain Australia

[10] Joshi N, Ravindran A, Mahajan V 2011 Investigations on chemical mutagen sensitivity in onion (Allium cepa L.). International J. of Bot. 7(3) 243-248

[11] Kamnetzky R and HD Rabinowitch 2002 Florogenesis. Editor Rabinowitch and Currah in Allium Crop Science. Recent Advances. Cabi Publishing. New York

[12] Kim JW and Soh WY 1996 Plant regeneration through somatic embryogenesis from suspension culture of Allium fistulosum L. Plant Sci. 114 215-220

[13] Kok CKR, Gebhardt R 2001 Garlic and health. Nutr. Metab. Cardiovasc Dis. 11 57-65

[14] Koul AK, RN Gohil, A Langer 1979 Prospect of breeding system. Euphytica. 28 457-464

[15] Kurniajati WS 2017 Perakitan Keragaman Bawang Merah (Allium cepa L. kelompok Agregatum) dengan Induksi Mutasi Sinar Gamma. Bogor (ID) - IPB Pr

[16] Mahandjiev AG, Kosturkova S, Mihov M 2001 Enrichment of Pisum sativum gene resource through the combined use of physical and chemical mutagens. Israel J. Plant Sci. 49 279-284

[17] Mantis AJ, Koidis PA, Kariaonmoglou PG, Panitsos AG 1979 Germination test for identification of γ-irradiated rice. Lebensmitten Wissenschaft Technologie. 12 330-332

[18] McCollum GD 1976 Onions and Allies. Pp. 186-190. in Evolution of Crop Plants. N. Simmonds (ed.). Longman, London, U. K

[19] Micke A, B Donini, and M Maluszynski 1993 Les mutations induites en amelioration des plantes. Mutation Breeding. Rev. 9 1-44

[20] Nurrohma 2004 The effect of gamma-ray radiation 60-co on the growth of garlic (Allium sativum L) var lambu hijau in the lowlands. Treatise of Scientific Seminars on Isotope and Radiation Applications

[21] Pospisil P 2010 Growing garlic from bulbils. The Canadian Organic Flower. Winter 2010 10-15

[22] Shankaracharya NB 1974 Symposium on spices in India, CFTRI, Mysore. pp.24-36

[23] Singh B, Datta PS 2010 Gamma irradiation to improve plant vigour, grain development, and yield attributes of wheat. Radiation Physics and Chemistry. 79 139–143

[24] Sukul NC, Das PK, De GC 1974 Studies on growth, yield and quality components in different garlic varieties. Nematologica, Bengal (India). 20 187-191

[25] Suniarjono H, Sudomo P, Hendi 1987 Potential yield of third-generation gamma (60-Co) irradiated shallot cultivar Sumenep. Bulletin Penelitian Hortikultura. 15(2) 261-266
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