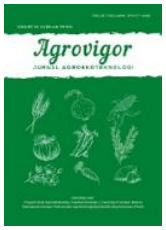
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Article

Morpho-agronomic characterization of Local Shallot Genotypes Induced by Gamma Irradiation

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ABSTRACT

Shallot (*Allium cepa* var. *aggregatum*) is an economically important horticultural crop in Indonesia, but limited genetic variability constrains breeding improvement. This study aimed to characterize morpho-agronomic traits and evaluate phenotypic diversity among local shallot genotypes subjected to gamma irradiation. Five shallot genotypes (Biru Lancor, Bima Brebes, Batu Ijo, Tajuk, and Keta Monca) were exposed to four irradiation doses (0, 3, 5, and 7 Gy) in a factorial randomized complete block design with three replications, comprising 240 plants. Quantitative growth traits were evaluated at two weeks after planting, while morphological characterization was conducted at eight weeks using UPOV descriptors. Data were analyzed using ANOVA and hierarchical clustering based on Gower's distance and average linkage. Genotype and irradiation dose significantly affected plant height, number of leaves, number of tillers, and leaf diameter, with a significant interaction observed only for number of leaves. At 7 Gy, plant height and leaf number decreased by 28.65% and 15.10%, respectively, compared with the control. Cluster analysis revealed phenotypic differentiation among 20 genotype–irradiation combinations, with B3S0 and B2S1 forming a distinct group, while B5S3, B4S3, and B3S3 exhibited closer morphological similarity. These findings provide preliminary information for identifying potential breeding materials, although further evaluation is required to confirm the stability of the observed variation.

INTRODUCTION

Shallot (*Allium cepa* var. *aggregatum*) is an important horticultural commodity in Indonesia due to its economic value, widespread consumption, and contribution to farmer income. Increasing demand for shallot requires continuous improvement in productivity, quality, and adaptability to diverse environmental conditions. However, shallot improvment is constrained by the limited genetic variability of cultivated populations, which restricts the availability of desirable traits for breeding programs. Shallot is commonly propated vegetatively through bulbs, allowing the maintenance of desirable parental characteristic but providing limited opportunities for generating new genetic variation. Therefore, expanding genetic and phonetypic variability is essential for developing improved shallot varieties with desirable agronomic characteristics and greater adaptability. Induced mutation using gamma irradiation is a promosing approach for generating novel variation in crop plants. Gamma rays can induce DNA alterations that may affect morphological, physiological, and agronomic characteristics. The effectiveness of mutation induction depends on several factors, including irradiation dose, plant genotype, and radiosensitivity of the treated materials (Mba, 2013; Oladosu et al., 2016). Previous studies have demonstrated that gamma irradiation can increase variability in shallot populations. Kurniajati et al. (2020) reported variation in quantitative traits following gamma irradiation., while Moeljani et al. (2022) showed that irradiation doses influenced genetic diversity and growth responses in shallot populations. These findings highlight the potential of gamma irradiation to expand variability in shallot breeding materials. However, limited information is available on the comparative morphoagronomic responses of five local Indonesian shallot genotypes—Biru Lancor, Bima Brebes, Batu Ijo, Tajuk, and Keta Monca—to different gamma irradiation doses. Furthermore, the combined evaluation of these genotypes using standardized morphological descriptors and phenotypic relationship analysis remains insufficiently explored.

Morphological characterization is essential for identifying phenotypic variation and distinguishing plant materials based on observable traits (Santoso et al., 2024; Probojati et al., 2023). Standardized descriptorsdeveloped by the International Union for the Protection of New Varieties of Plants (UPOV)enables systematic evaluation of morphological characteristics, including foliage, leaf, and bulb (Perković et al., 2021). In addition, multivariate approaches, particulary cluster analysis can reveal phenotypic relationships among genotypes based on morphological similarity and support the identification of divergent breeding materials (Mohammadi & Prasanna, 2003; Ramadhani et al., 2020; Hadiyanti et al., 2025). Combining UPOV-based morphological characterization, quantitative morphoagronomic traits, and cluster analysis provides an integrated approach to evaluating phenotypic variation induced by gamma irradiation. Such as integrated approach is important for identifying promosing mutant population and supporting the selection of potential breeding materials for future shallot improvement.

This study aimed to characterize morphoagronomic traits and evaluate phenotypic diversity among local Indonesian shallot genotypes subjected to different gamma irradiation doses using quantitative traits, UPOV morphological descriptors, and cluster analysis. The findings are expected to provide information on irradiation induced phenotypic variation and support the identification of promising plant material for further evaluatin in shallot breeding programs.

MATERIAL AND METHODS

Research Site and Plant Materials

The research was conducted from May to July 2026 at the greenhouse of the Faculty of Agriculture, Universitas Kadiri, Kediri, Indonesia. During the experimental period, greenhouse temperatures ranged from 25 to 32 °C, with relative humidity of 45 – 86% and an average daily sunlight exposure of approximately 7 hours, based on direct observation. Gamma irradiation was performed at the irradiation facility of the National Research and Innovation Agency (BRIN), Pasar Jumat, South Jakarta, Indonesia. Five local Indonesian shallot genotypes were used as plant materials, namely Biru Lancor (B1), Bima Brebes (B2), Batu Ijo (B3), Tajuk (B4), and Keta Monca (B5). Healthy and uniform bulbs of comparable size, without physical damage or visible disease symptoms, were selected for irradiation and subsequent planting.

Experimental Design and Gamma Irradiation Treatment

The experiment was arranged using a factorial Randomized Complete Block Design (RCBD) with two factors: five shallot genotypes namely Biru Lancor (B1), Bima Brebes (B2), Batu Ijo (B3), Tajuk (B4), and Keta Monca (B5) and

four gamma irradiation doses, namely: 0 Gy (S0), 3 Gy (S1), 5 Gy (S2), and 7 Gy (S3). The experiment consisted of 20 treatment combinations with three-replication, resulting in 60 experimental units. Each experimental unit comprised four plants grown individually in polybags, giving a total of 240 plants. Gamma irradiation was applied to shallot bulbs at the predetermined doses at BRIN facility, while non-irradiated bulbs (0 Gy) served as controls. Following irradiation, the treated bulbs were planted to establish the M1 generation for phenotypic evaluation.

Planting and Maintenance

Following irradiation, Shallot bulbs were planted individually in polybags containing a mixture of soil and goat manure at a ratio of 2:1 (v/v). No additional fertilizer was applied during the growing period. Irrigation was performed every two days using approximately 0,5 L of water per polybag, according to the growing medium's field capacity. Pest management was carried out mechanically when grasshoppers or leaf-feeding caterpillars were observed. All treatments received uniform cultivation practices under greenhouse conditions. No plant mortality or visible morphological abnormalities were observed in either irradiated or control plants during the experimental period. Consequently, all 240 plants were included in the phenotypic evaluation.

Plant Morpho-agronomic characterization

Morpho-agronomic characterization including quantitative growth traits and morphological descriptors based on the UPOV guidelines for shallot (Naktuinbow, 2010). Four quantitative growth traits were evaluated at two weeks after planting (WAP): plant height, number of leaves, number of tillers, and leaf diameter. Plant height was measured from the bulb neck to the tip of the longest leaf in each plant clump. Leaf diameter was measured at the middle portion of three leaves representing small, medium, and large leaf sizes using a vernier caliper, with measurements recorded in millimeters (mm) and averaged. The number of leaves was determined by counting all green leaves within each clump, while the number of tillers was recorded based on the number of bulbs that had developed as distinct divisions within each clump. Four plants were observed per experimental unit, and their measurements were averaged to obtain a single value for statistical analysis. Morphological characterization was conducted destructively at eight WAP using UPOV-based descriptors. The evaluated characteristics included foliage attitude (FA), foliage waxiness (FW), intensity of green colour (FIG), foliage cranking (FC), leaf length (LL), leaf diameter (LD), tendency to split into bulblets (BT), bulb size (BS), bulb diameter (BD), height-to-diameter ratio (BRH), position of maximum diameter (BPM), neck width (BWN), bulb shape, stem end shape (BSSE), root end shape (BSRE), dry skin colour characteristics (BCDS, BIBC, BHCD), and epidermis coloration of fleshy scales (BCEF). Morphological traits were assessed using the corresponding UPOV descriptor categories to evaluate phenotypic variation among genotype–irradiation combination

Phenotypic Cluster Analysis

Phenotypic relationships among shallot genotype–irradiation combinations were evaluated using hierarchical cluster analysis based on morphological descriptor data collected at eight WAP. Gower's distance was used to measure phenotypic dissimilarity, while the average linkage method was applied for hierarchical clustering. The analysis was performed using PBSTAT-CL version 2.2.1 (Suwarno et al., 2008). The resulting dendrogram was used to visualize phenotypic relationships among the evaluated genotype–irradiation combinations.

Statistical Analysis

Quantitative data for plant height, number of leaves, number of tillers, and leaf diameter, recorded at two WAP,were subjected to analysis of variance (ANOVA) based on factorial Randomized Complete Block Design (RCBD) using SAS version 9.0. The mean values of four plants within each experimental unit were used as the observations for statistical analysis. The statistical model was:

$$Y_{ijk}=\mu+G_i+D_j+(GD)_{ij}+K_k+\varepsilon_{ijk} \quad (1)$$

Yijk : observed value of genotype *i*, irradiation dose *j*, and block *k*;
μ : overall mean;

Gi : the genotype effect *i*;
Dj : the irradiation dose effect *j*;
(GD)ij : interaction effect between genotype and irradiation dose;
Kk : block effect; and
εijk : the experimental error.

Significant treatment effect were further analyzed using the Least Significant Difference (LSD) test at 5% significance level ($p<0.05$).

RESULT AND DISCUSSION

Variation of Morphoagronomic Traits in Shallot M1 Mutants Induced by Gamma Irradiation

Analysis of variance revealed that genotype and gamma irradiation dose significantly affected all evaluated morphoagronomic traits of shallot M1 plants (Table 1). Genotype had highly significant effects on plant height andnumber of leaves ($p < 0,01$), and significant effect on number of tillers and leaf diameter ($p < 0,05$).

Gamma irradiation also had highly effects on plant height, number of leaves, and leaf diameter, whereas its effect on number of tillers was significant at $p < 0,05$. . The genotype × irradiation interaction was significant only for number of leaves, suggesting that responses in leaf production varied depending on genotype and irradiation dose. These result demonstrate phenotypic variation among local shallot genotypes and their responses to gamma irradiation. Similar findings have been reported Kurniajati et al., 2020; and Moeljani et al., 2022, who observed variation in quantitative characteristics following gamma irradiation in shallot populations

Table 1. Mean squares from the analysis of variance for morphoagronomic traits of five shallot genotypes under different gamma irradiation doses

Source of variation	df	Traits			
		Plant height	Number of leaves	Number of tillers	Leaf diameter
Genotype (G)	4	263.91 **	279.06 **	12.36 *	0.45 *
Irradiation (I)	3	618.90 **	192.57 **	13.27 *	1.30 **
Replication	2	43.60 ns	66.42 ns	11.46 ns	0.64 *
Genotype x Iradiation (G x I)	12	69.64 ns	45.46 *	4.25 ns	0.14 ns
CV(%)		23,67	20,08	34,5	20,4

ns = not significant; * significant at $p < 0.05$; ** significant at $p < 0.01$.

Significant differences among shallot genotypes were observed for all morphoagronomic traits (Table 2). Batu Ijo exhibited the greatest plant height (36.34 cm), while Keta Monca had the largest leaf diameter (2.24 cm). Biru Lancor produced the highest number of leaves (30.12 leaves) and the number of tillers (7.22 tillers), indicating relatively vigorous vegetative growth. These result demonstrate phenotypic variation among local shallot genotypes in plant architecture and vegetative development. Such differences may reflect inherent genetic variation influenching growth regulation, leaf development, and tiller formation. Khadka et al., (2021) also emphasized the importance of genotype-dependent characteristics in crop improvement. From a breeding perspective, genotypes with desirable vegetative traits may provide useful materials for further evaluation, although their yield potential and trait stability remain to be determined.

Gamma irradiation significantly influenced vegetative growth, with different responses across irradiation doses (Table 3). Plant height decreased from 37.0 cm in the control treatment to 26.4 cm at 7 Gy, while leaf diameter declined from 2.3 cm to 1.8 cm. The highest numerical mean for number of leaves was recorded at 3 Gy (26.7), whereas number of tillers was highest at 5 Gy (6.7). These patterns suggest that moderate irradiation doses may maintain vegetative growth, while higher doses tend to suppress plant development. Gamma irradiation can induce DNA damage and reactive oxygen species, potentially disturbing cell division, elongation, and physiological processes involved in plant growth (Wi et al., 2007; Kovács & Keresztes, 2002). However, these cellular mechanisms were not directly investigated in the present study. The observed growth reduction at 7 Gy may therefore reflect

increased irradiation stress, emphasizing the importance of selecting appropriate irradiation doses for mutation-breeding programs.

Table 2. Effect of shallot genotypes on morphoagronomic traits of M1 generation

Genotypes of Shallot	Plant height	Number of leaves	Number of tillers	Leaf diameter
Biru Lancor	32,1 ab	30,12 a	7,22 a	1,96 bc
Bima Brebes	33,96 ab	24,04 b	5,92 b	1,94 c
Tajuk	30,36 bc	21,04 c	5,26 b	2,00 abc
Batu Ijo	36,34 a	23,6 bc	5,89 b	2,18 ab
Keta Monca	27,69 c	23,1 bc	6,17 ab	2,24 a
LSD 5%	4,36	2,81	1,2	0,24

Values followed by the same letter within the same column are not significantly different according to LSD test at 5% probability.

Table 3. Effect of gamma irradiation doses on morphoagronomic traits of shallot M1 plants.

Doses Irradiation	Plant height	Number of leaves	Number of tillers	Leaf diameter
0 Gy	37,0 a	24,5 b	5,9 a	2,3 a
3 Gy	33,9 a	26,7 a	6,5 a	2,1 a
5 Gy	31,0 ab	25,5 ab	6,7 a	2,0 a
7 Gy	26,4 b	20,8 b	5,2 b	1,8 b
LSD 5%	7,34	9,05	3,76	0.89

Values followed by the same letter within the same column are not significantly different according to LSD test at 5% significance level.

The genotype × irradiation interaction significantly affected number of leaves (Table 4), indicating genotype-dependent responses to irradiation treatment. Biru lancor irradiated at 3 Gy produced the highest number of leaves at 3 Gy (33.21 cm), whereas Tajuk at 7 Gy exhibited the lowest value (12.38 cm). These differences may be associated with genotype-dependent radiosensitivity, as genetic background can influence the ability of plants to maintain growth under irradiation-induced stress. Similar genotype-dependent responses to mutagenic treatments have been reported by Oladosu et al., (2016). Although the genotype × irradiation interactions were not statistically significant for plant height, number of tillers, and leaf diameter, differences in treatment means may still be considered as descriptive response trends. From a breeding perspective, the observed variation in leaf production provides preliminary information for evaluating genotype-specific irradiation responses. Nevertheless, further selection and evaluation in subsequent generations are required to confirm the stability of these characteristics.

Table 4. Interaction effect between shallot genotypes and gamma irradiation doses on number of leaves in the M1 generation

Genotypes of Shallot	Doses Irradiation			
	0 Gy	3 Gy	5 Gy	7 Gy
Biru Lancor	27,95 ab	33,21 a	30,54 ab	28,79 ab
Bima Brebes	24,83 ab	25,75 ab	24,21 ab	21,38 ab
Tajuk	25,38 ab	22,79 ab	23,63 ab	12,38 b
Batu Ijo	25,21 ab	24,00 ab	24,50 ab	20,67 ab
Keta Monca	19,17 ab	27,88 ab	24,42 ab	20,96 ab

Values followed by the same letter are not significantly different according to LSD test at 5% probability (20,25)

Phenotypic Diversity Among Five Shallot Genotypes

Cluster analysis based on 20 UPOV morphological descriptors revealed phenotypic differentiation among the shallot genotype - irradiation combinations (Figure 1). Hierarchical clustering using Gower's distance and average linkage identified three groups at the selected major branching level. Cluster I consisted of Batu Ijo without irradiation (B3S0) and Bima Brebes irradiated at 3 Gy (B2S1), which were clearly separated from the remaining combinations. Cluster II comprised 11 combinations, while Cluster III contained seven combinations. These groupings reflected differences in morphological characteristics among the evaluated populations.

The clusters exhibited distinct morphological profiles based on foliage and bulb descriptors (Table 5). Cluster I was characterized by higher descriptor scores for number of leaves per pseudostem, intensity of green colour, leaf length, and bulb neck width. Cluster II predominantly exhibited lower scores for leaf length, leaf diameter, bulb size, and bulb diameter. Cluster III showed relatively higher scores for leaf length, bulb diameter, and bulb neck width than Cluster II, although substantial variation remained among individual descriptors. These findings indicate that phenotypic clustering reflected differences in both vegetative and bulb morphological characteristics.

Table 5. Dominant morphological descriptor score and their frequencies across phenotypic clusters of shallot genotype irradiation combinations

UPOV descriptor	Cluster I (n = 2)	Cluster II (n = 11)	Cluster III (n = 7)
Number of leaves per pseudostem (NL)	Score 8 (2/2)	Scores 5 and 6 (5/11 each)	Score 6 (7/7)
Intensity of green colour (FIG)	Dark, score 7 (2/2)	Light, score 3 (7/11)	Medium and dark, scores 5 and 7 (3/7 each)
Leaf length (LL)	Long, score 7 (2/2)	Score 1 (5/11)	Medium, score 5 (4/7)
Leaf diameter (LD)	Scores 2 and 5 (1/2 each)	Score 1 (11/11)	Score 3 (4/7)
Bulb size (BS)	Scores 3 and 4 (1/2 each)	Score 1 (10/11)	Score 1 (4/7)
Bulb diameter (BD)	Scores 3 and 4 (1/2 each)	Score 1 (9/11)	Score 3 (5/7)
Bulb neck width (BWN)	Score 7 (2/2)	Scores 1 and 3 (5/11 each)	Score 5 (4/7)
Dry skin colour (BCDS)	Red, score 7 (2/2)	White, score 1 (10/11)	White, brown, and red, scores 1, 5, and 7 (2/7 each)

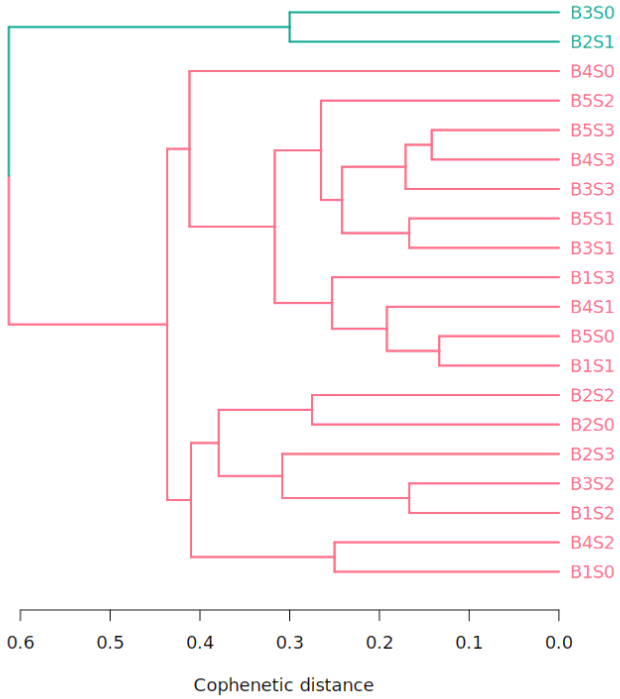


Figure 1. Cluster analysis of shallot genotypes and gamma irradiation mutants

Values indicate the most frequent UPOV descriptor scores, with their frequencies within each cluster shown in parentheses. Multiple values indicate equally frequent scores. Cluster membership was determined from the selected major branches of Figure 1. Scores should be interpreted according to the corresponding UPOV descriptor categories.

The separation of B3S0 and B2S1 from the remaining populations suggests that these combinations possessed relatively distinct morphological profiles. In contrast, B5S3, B4S3, and B3S3, all receiving 7 Gy irradiation, exhibited close phenotypic relationships in the dendrogram. However, populations exposed to similar irradiation doses were not consistently grouped together, indicating that phenotypic similarity was not determined solely by irradiation intensity. These findings may reflect differences in genotype-dependent morphological responses following irradiation. Morphological clustering is therefore useful for identifying phenotypic relationships and evaluating variation among breeding materials (Mohammadi & Prasanna, 2003).

A breeding perspective, phenotypically distinct populations may represent potential materials for further characterization and selection, particularly when they possess desirable vegetative or bulb characteristics. Nevertheless, phenotypic differences observed in the M1 generation may result from irradiation-induced physiological effects as well as genetic changes. Therefore, evaluation in subsequent generations is essential to determine whether the observed morphological variation is stable and heritable before selecting promising mutant lines for shallot improvement programs.

CONCLUSION

Gamma irradiation influenced morphoagronomic traits and was associated with phenotypic variation among local shallot M1 populations. Genotype and irradiation dose significantly affected all evaluated vegetative traits, while their interaction was significant only for the number of leaves. Biru Lancor exhibited the highest numbers of leaves and tillers, Batu Ijo showed the greatest plant height, and Keta Monca had the largest leaf diameter. The highest irradiation dose (7 Gy) generally tended to suppress vegetative growth. UPOV-based morphological characterization and cluster analysis revealed phenotypic differentiation among genotype–irradiation combinations, particularly in foliage and bulb characteristics. These findings provide preliminary information for identifying potential breeding materials, although further evaluation in subsequent generations is required to confirm the stability and heritability of the observed phenotypic variation.

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AUTHORS CONTRIBUTIONS

UFH: designed the experiment, conducted the research, analyzed the data; Writing – original draft. **RTP:** experimental implementation, data collection, and manuscript review. **AHNP**: data interpretation and manuscript improvement. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

Khadka, R., Maraseni, T., & Bhandari, S. (2021). Genotypic variability and correlation analysis of growth and yield traits in shallot (*Allium cepa* L. Aggregatum Group). *Plants, 10*(9), 1871. https://doi.org/10.3390/plants10091871

Kovács, E., & Keresztes, Á. (2002). Effect of gamma and UV-B/C radiation on plant cells. *Micron, 33*(2), 199–210. https://doi.org/10.1016/S0968-4328(01)00012-9

Kurniajati, W. S., Sobir, & Aisyah, S. I. (2020). Penentuan dosis iradiasi sinar gamma dalam meningkatkan keragaman untuk perbaikan karakter kuantitatif bawang merah (*Allium cepa* var. *aggregatum*). *Jurnal Ilmiah Aplikasi Isotop dan Radiasi, 16*(2), 59–68. https://doi.org/10.17146/jair.2020.16.2.5962

Moeljani, I. R., Makziah, & Wahyuni, E. (2022). Estimation of genetic diversity and LD50 determination of red onion variety Bauji results in gamma irradiation 60Co. *Jurnal Hortikultura Indonesia, 12*(3), 183–190. https://doi.org/10.29244/jhi.12.3.183-190

Mohammadi, S. A., & Prasanna, B. M. (2003). Analysis of genetic diversity in crop plants—salient statistical tools and considerations. *Crop Science, 43*(4), 1235–1248. https://doi.org/10.2135/cropsci2003.1235

Mba, C. (2013). Induced mutations unleash the potentials of plant genetic resources for food and agriculture. *Agronomy, 3*(1), 200–231.https://doi.org/10.3390/agronomy3010200

Naktuinbow. 2010. Calibration book onion and shallot. https://www.naktuinbouw.nl/sites/default/files/Onion%20%26%20sh allot%20calibration%20book.pdf. [15 September 2016].

Hadiyanti, N., Probojati, R.T., Kustiani, E., Sari, S.P. The effect of different growing locations on the morphological characteristics and flavonoid content of clove plants (*Syzygium aromaticum*). *Int. J. of Sust. Agri. Res.*, 12(4).181-191. https:/ / doi.org/ 10.18488/ijsar.v12i4.4492

Oladosu, Y., Rafii, M. Y., Abdullah, N., Hussin, G., Ramli, A., Rahim, H. A., Miah, G., & Usman, M. (2016). Principle and application of plant mutagenesis in crop improvement: A review. *Biotechnology & Biotechnological Equipment, 30*(1), 1–16. https://doi.org/10.1080/13102818.2015.1087333

Perković, J., Major, N., Ban, D., Cvitan, D., & Ban, S. G. (2021). Shallot species and subtypes discrimination based on morphology descriptors. *Plants, 10*(1), 60. https://doi.org/10.3390/plants10010060

Probojati, R.T., Hadiyanti, N., Lisanty, N., Pamujiati, A.D., Firdausi, M.R. (2023). Exploration of Local Durian (Durio zibethinus Murr.) from Semen Sub-District, Kediri, East Java Based on Morphological Character and Geographical Factor. Journal Pertanian Tropik, 10(1): 1-6 https://doi.org/10.32734/jpt.v10i1,%20April.11663

Santoso, Y., Probojati, R. T., Hapsari, L., Supandji, Kustiani, E. (2024). Variation and clustering analysis of several species of soursop family (Annonaceae) based on vegetative morphology characters. *Agrovigor: Jurnal Agroekoteknologi*, 17(1), 28-36. https://doi.org/10.21107/agrovigor.v17i1.24845

Suwarno WB, Sobir, Aswidinnoor H, Syukur M (2008). PBSTAT: A web-based statistical analysis software for participatory plant breeding. Proceedings of the 3rd International Conference on Mathematics and Statistics, Bogor, Indonesia, pp. 852–858

Wi, S. G., Chung, B. Y., Kim, J. S., Kim, J. H., Baek, M. H., Lee, J. W., & Kim, Y. S. (2007). Effects of gamma irradiation on morphological changes and biological responses in plants. *Micron, 38*(6), 553–564. https://doi.org/10.1016/j.micron.2006.11.002