International Journal of Agricultural Technology 2025 Vol. 21(5):2083-2096
DOI: https://doi.org/10.63369/ijat.2025.21.5.2083-2096
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Variation in morphological traits of Rubaru local shallot from Sumenep, Madura Island, and its potential for future agricultural innovation

Wati, H. D.[1], Waluyo, B.[2], Ekawati, I.[1*] and Fajarianingtyas, D. A.[1]

[1]Faculty of Agriculture Wiraraja University, Sumenep, Indonesia; [2]Faculty of Agriculture Brawijaya University, Malang, Indonesia.

Wati, H. D., Waluyo, B., Ekawati, I. and Fajarianingtyas, D. A. (2025). Variation in morphological traits of Rubaru local shallots from Sumenep, Madura Island and its potential for future agricultural innovation. International Journal of Agricultural Technology 21(5):2083-2096.

Abstract The results showed significant variability in traits such as bulb number and weight, which were influenced by both environmental and genetic factors. Conversely, traits, including plant height and harvest age had genetic stability. The PCA results showed three principal components accounting for 80.92% of the total morphological variability. The components showed traits such as bulb size, weight, and plant growth attributes as key contributors to the observed diversity. The cluster analysis categorized the accessions based on morphological similarities, underscoring their potential for adaptation and selective breeding. The analysis results showed the importance of morphological diversity in supporting breeding innovations, optimizing land management practices, and promoting sustainable agriculture in challenging environments. These contributions addressed the critical needs such as climate resilience and food security. To build on such insights, further genetic examinations are recommended to complement morphological analysis presented in this research.

Keywords: Morphological traits, Rubaru local shallot, Genetic variation, Agricultural innovation, Madura Island

Introduction

Shallot (*Allium ascalonicum* L) is one of the essential horticultural commodities in Indonesia's agricultural sector because it has high strategic and economic value. The commodity serves as the primary source of income for thousands of farmers and is widely used as a spice in Indonesian cuisine. Therefore, shallot plays a crucial role in both food security and the national economy. Madura Island, characterized by its lowland and dry climate, is home to Rubaru, a region in Sumenep Regency where 87.3% of the agricultural land is dedicated to the cultivation of shallot and corn throughout the year (Ramadhani *et al.*, 2024). This region has long been recognized as one of the main centers of

* **Corresponding Author:** Ekawati, I.; **Email:** idaekawati@wiraraja.ac.id

shallot production, yielding local varieties with distinct characteristics (Rachmawati *et al*., 2023; Triharyanto *et al*., 2020; Yofananda *et al*., 2021). According to Major *et al*. (2018), local varieties generally had a wide range of unique morphological and biochemical traits.

Research on the morphological diversity of shallots has been conducted in various regions globally, including Ethiopia, Turkey, Iran, Croatia, and Indonesia. These previous investigations aimed to assess the potential for adaptation, genetic variation, and the selection of superior plants (Beşirli, 2024; Fitriana and Susandarini, 2019; Ghahremani-Majd and Dashti, 2014; Tabor *et al*., 2024). Other investigations have also shown that traits such as bulb size, color, and leaf shape significantly influenced the productivity and adaptation of shallot under varying environmental conditions (Anugrah *et al*., 2024; Pratiwi *et al*., 2020). To develop superior local varieties, it is essential to thoroughly understand morphological variation as the foundation for genetic selection and improvement. While numerous investigations on shallot varieties have been conducted in Indonesia (Anugrah *et al*., 2024; Devy *et al*., 2021; Fitriana and Susandarini, 2019; Rachmawati *et al*., 2023; Sari *et al*., 2017), research that specifically focused on local Rubaru shallot remained limited. Most existing investigations have concentrated on identifying the key morphological traits that contributed to the total variation within the Rubaru shallot population.

This research is necessary due to the unique adaptive characteristics of Rubaru shallot varieties (Maharijaya *et al*., 2023). However, there is a lack of comprehensive information regarding morphological variation within the existing population. This gap needs to be addressed by mapping both qualitative and quantitative morphological traits of the Rubaru variety. Furthermore, this research explores the potential of such variety in the development of a superior local Rubaru shallot. Documenting and preserving morphological variation ensures the conservation of genetic resources, which are crucial for future varietal improvement. Moreover, examining the diversity of morphological traits provides opportunities for innovative breeding programs that can adapt to future agricultural challenges, particularly in regions like Madura, with specific environmental conditions. By developing varieties that are more resilient to environmental changes and disease, the innovations contribute to sustainable agricultural practices (Dewi *et al*., 2024; Maulidha *et al*., 2024).

This research aimed to identify and characterize morphological traits of eight Rubaru local shallot accessions to determine the key traits contributing most to the total variation among the shallot population. Additionally, it aimed to classify such accessions based on morphological traits.

Materials and methods

The research was conducted at the shallot production center in Sumenep Regency, specifically in Mandala Village, Rubaru District, from June to August 2024. The analysis began with an exploratory survey aimed at identifying morphological and agronomic traits of local Rubaru shallot, based on descriptors provided by local farmers. The respondents were selected in accordance with specific criteria outlined in the questionnaire, which included farmers who had been cultivating Rubaru shallot for at least 10 years and who managed a minimum land area of 100 m^2. A total of eight farmers who met these criteria were identified as the sources of local shallot accessions, numbered one through eight.

Plant samples were purposively selected from farmers whose crops had reached harvest age. Sampling was conducted by placing a 1m x 1m bamboo frame on the Rubaru shallot plantations. From within the frame, 16% of shallot clumps were selected for analysis. The next stage included identifying morphological traits based on the descriptors provided by the farmers, and the data was analyzed descriptively.

This step covered a desk analysis, where the samples were compared with the description list from the International Plant Genetic Resources Institute (IPGRI). Morphological traits of shallot were then recorded. The observation method was used, wherein plants' components were visually assessed to collect qualitative data. Both individual plants and multiple sections were measured to collect quantitative data. The collected data were categorized according to the descriptor criteria, focusing on the biological status of the accessions, which were classified as traditional cultivars or landraces.

The observed traits included plant height, the number of leaves per clump, bulb width, bulb length, bulb number, bulb wet weight, leaf shape, leaf color, flower shape, flower color, and bulb color. Photographs of the plant samples and shallot bulb shapes from various farmer accessions were also taken for reference.

Quantitative morphological traits were statistically analyzed to determine the mean, standard deviation, and diversity coefficient. Subsequently, Principal component analysis (PCA) was conducted to analyze variation in these morphological traits. The number of principal components was determined an eigenvalue greater than 1, and traits contributing to maximum diversity were identified by a loading factor greater than 0.5. Additionally, hierarchical cluster analysis was used to group the eight Rubaru shallot accessions based on the similarity of their quantitative morphological traits. Euclidean distance, which measured the geometric distance between two objects, was applied to assess morphological similarities (Hageman *et al*., 2012; Hasan *et al*., 2024). Moreover, the Single Linkage method was used for grouping the accessions based on their similarities.

Results

Descriptive analysis of the morphological trait

The quantitative morphological traits of eight local Rubaru shallot accessions, which were statistically analyzed, are presented in Table 1. The mean values of each morphological character provided an overview of the key traits of the commodity. Traits with high standard deviations showed substantial variability. The most variable traits among shallot accessions were the number of bulbs and bulb weight, with coefficients of variation of 33.60% and 35.92%, respectively. The variation suggested that environmental and genetic factors significantly influenced traits. In contrast, variation in tuber length was relatively low, with a coefficient of variation of 10.08%. Plant height, harvest age, and flower age were more stable, suggesting these traits were likely influenced by consistent genetic factors across shallot accessions.

Table 1. Descriptive analysis of quantitative morphological trait

Character	Minimum	Maximum	Mean	Standard deviation	Variation coefficient (%)
Plant height	32.33	36.33	34.7088	1.41944	4.09
Leaf number	12.33	22.67	18.0438	3.45392	19.14
Bulb number	2.67	6.67	4.5850	1.54067	33.60
Bulb length	20.87	29.43	25.2450	2.71848	10.08
Bulb width	13.90	28.87	22.8100	5.50849	24.15
Bulb weight	3.67	10.33	6.9175	2.48478	35.92
Flower age	40	47	42.00	2.726	6.49
Harvest age	55.00	60.00	58.2500	1.75255	3.01

Table 2. Descriptive of qualitative morphological trait

Parameter	Aksesi 1	Aksesi 2	Aksesi 3	Aksesi 4	Aksesi 5	Aksesi 6	Aksesi 7	Aksesi 8
BFC	Violet/white	Violet/white	Violet/white	Violet/white	Violet/white	Violet/white	Violet/white	Violet/white
FC	Green	Green	Green	Green	Green	Green	Green	Green
FWC	White	White	White	White	White	White	White	White
BS	Ovate (elongated oval)	Ovate (elongated oval)	Ovate (elongated oval)	Ovate (elongated oval)	Ovate (elongated oval)	Ovate (elongated oval)	Ovate (elongated oval)	Ovate (elongated oval)
BST	Thin	Thin	Thin	Thin	Thin	Thin	Thin	Thin
MDP	Towards Root End	Towards Root End	Towards Root End	Towards Root End	Towards Root End	At Middle	Towards Root End	Towards Root End
SSE	Strongly Sloping	Strongly Sloping	Strongly Sloping	Strongly Sloping	Strongly Sloping	Strongly Sloping	Strongly Sloping	Strongly Sloping
SBC	Brown	Pink	Brown	Brown	Brown	Brown	Brown	Brown

Note: *Based on The Descriptor for Allium sp.* (IPGRI, 2001), **Bulb flesh color (BFC)**: 1. White, 2. Cream, 3. Green/white, 4. Violet/white. **Foliage color (FC)**: 1. Light green, 2. Yellow-green, 3. Green, 4. Grey-green, 5. Dark green, 6. Bluish green, 7. Purplish-green. **Flower color (FWC)**: 1. White, 2. Cream, 3. Yellow, 4. Pink, 5. Lilac, 6. Blue, 7. Purple, 8. Green, 9. Red. **Bulb shape (BS)**: 1. Flat, 2. Flat globe, 3. Rhomboid, 4. Broad oval, 5. Globe, 6. Broad elliptic, 7. Ovate (elongated oval), 8. Spindle, 9. High top. **Bulb skin thickness (BST)**: 3 Thin, 5 Medium, 7 Thick. *Based on the Onion and Shallot Calibration Book (Naktuinbow, 2010),* ***the maximum diameter position (MDP)****:* 1. Towards stem end, 2. At Middle, 3. Towards Root End. **Shape of stem end) (SSE):** 1. Depressed, 2. Flat, 3. Slightly Raised, 4. Rounded, 5. Slightly Sloping, 6. Strongly Sloping. **Skin bulb color (SBC)**: 1. White, 2. Grey, 3. Green, 4. Yellow, 5. Brown, 6. Pink, 7. Red

Variation in qualitative morphological traits of both plants and tubers showed relatively low diversity, as detailed in Table 2. Most of the accessions examined showed uniform traits, suggesting that they likely share a common ancestor. Accession 2 had a pink bulb skin color, while the other accessions had brown skin. In contrast, Accession 6 differed from the others in the position of the maximum bulb diameter, which was located at the center of the tuber. These morphological differences might be related to local adaptation, possibly influenced by the plants' response to specific environmental conditions, such as stress.

PCA result of quantitative morphological trait

The total variance and principal components derived from the PCA of the morphological diversity of 8 Rubaru local shallot accessions are presented in Table 2. Three principal components were identified, each explaining a specific percentage of the total variance in morphological traits of the local commodity in Rubaru. The cumulative variance explained by the three components was 80.916%, showing that they represented a substantial portion of the morphological variability of Rubaru shallot accessions.

The first principal component (PC1) explained 38.346% of the total variance, showing that it accounted for the majority of the variability in the dataset. The second principal component (PC2) explained 27.382% of the variance, contributing significantly to the differentiation of shallot accessions. The third principal component (PC3) accounted for 15.188% of the variance, adding further insight into the diversity not explained by PC1 and PC2.

PC1 was primarily influenced by characteristics such as the number of leaves, number of bulbs, flower age, and harvest age, all of which have relatively high positive loading factors. This suggested that PC1 was largely shaped by the plants' growth traits and age. PC2, with high positive loading from bulb width and weight, appeared to be related to the size and mass of the bulbs. Lastly, PC3 was predominantly influenced by bulb length and plant height, with bulb length being the dominant factor. Therefore, PC3 could be interpreted as a component reflecting the vertical physical size of the bulbs and plants.

Table 3. Loading factor and eigenvalue generated from PCA

Character	PC1	PC2	PC3
Plant height	-.010	.520	**.730**
Leaf number	**.742**	.379	.193
Bulb number	**.699**	.523	-.055
Bulb length	.077	-.015	**.949**
Bulb width	-.001	**.950**	.090
Bulb weight	-.030	**.692**	.578
Flower age	**.744**	-.179	-.312
Harvest age	**.834**	-.292	.285
Eigenvalue	3.068	2.191	1.215
Variance (%)	38.346	27.382	15.188
Cumulaative (%)	38.346	65.728	80.916

Results of cluster analysis

A cluster analysis was conducted on eight local shallot accessions in Rubaru based on their morphological traits, resulting in a dendrogram (Figure 1) that showed the grouping of shallot accessions. The dendrogram showed that accessions 2 and 5 were more closely related than others, with a Euclidean distance of 2.485. These two accessions had highly similar morphological properties, suggesting a possible shared genetic background or adaptation. Therefore, further analysis was required to assess genetic similarity between accessions 2 and 5, using methods such as SSR, RFLP, RAPD, and AFLP. Accession 1, with a Euclidean distance of 2.922 from accession 2, also joined this group. Similarly, accession 7, with a slightly larger Euclidean distance of 3.491, formed a cluster with accessions 2, 5, and 1.

Accessions 6 and 8 formed a separate cluster, with a nearest Euclidean distance of 2.490. The accessions shared similar morphological traits but differed from accessions 2 and 5. Accessions 4 and 3 joined the same group as accessions 6 and 8, even though at greater distances, showing lower similarity compared to the other clusters. This cluster showed more significant variation in morphological traits, suggesting that it could be an area of interest for further research on local adaptation. The research was particularly valuable for addressing climate change, which tended to impact food security and support future agricultural sustainability.

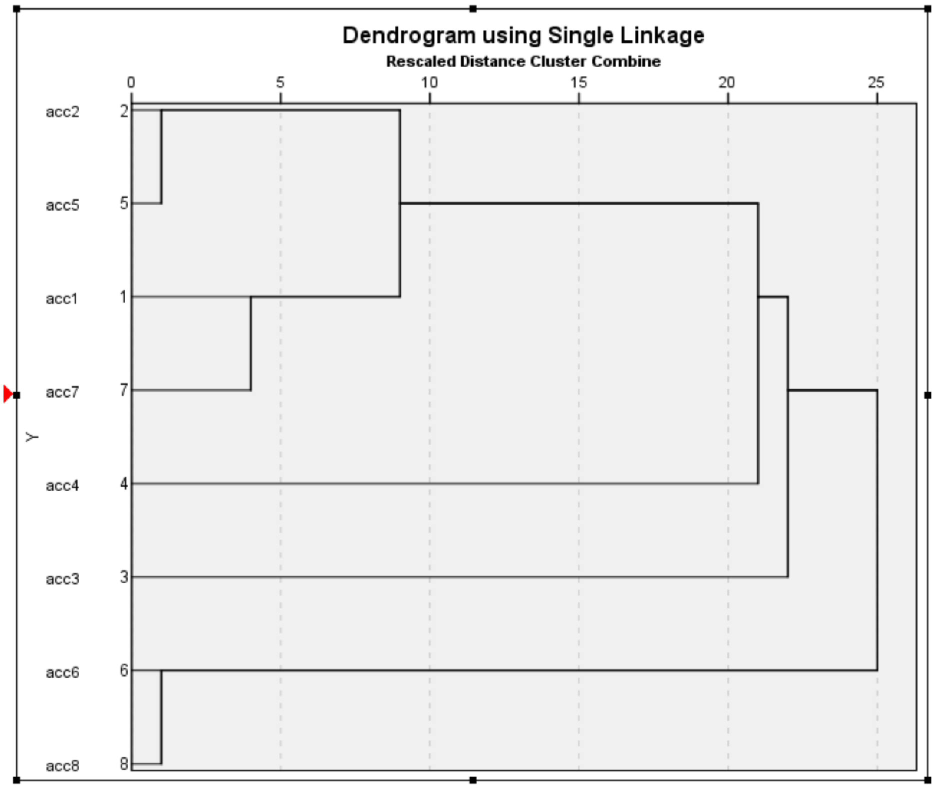

Figure 1. Dendrogram of eight accessions of Rubaru Local Shallot based on morphological traits

Discussion

This research showed that Rubaru's local shallot possessed significant potential for breeding programs due to its rich genetic diversity. The stability of certain traits made the commodity a suitable candidate for genetic selection. In contrast, variation in other traits offered opportunities for further exploration to improve adaptability to environmental changes or to enhance yield potential (Azam *et al*., 2024). The use of molecular methods to assess genetic similarities could complement this research, aiding in the development of superior varieties (Placide *et al*., 2015).

The analysis provided valuable insights into the morphological diversity of Rubaru local shallot through descriptive analysis, cluster analysis, and PCA. PCA was a multivariate statistical method that created PC by combining data from multiple variables observed on the same subjects (Greenacre *et al*., 2022). Cluster analysis also showed distinct groupings of morphological traits within the accessions, signifying unique characteristics present in different subgroups. These results could guide future breeding programs and conservation efforts aimed at preserving the genetic diversity of the Rubaru local shallot.

The research identified significant variation in bulb number and weight, with coefficients of variation of 33.60% and 35.92%, respectively. This suggested that both genetic and environmental factors strongly influence traits. Variation presented opportunities to breed varieties with improved yields under specific environmental conditions (Garcia *et al*., 2004). In contrast, traits such as plant height, harvest age, and flower age had higher stability with low coefficients of variation, showing that traits were more influenced by genetic factors than environmental ones (Abdi and Williams, 2010). This stability made traits useful as indicators in breeding programs aimed at producing plants more adaptable to varying environmental conditions (Ceccarelli *et al*., 2010). Other research has shown the importance of morphological variation among shallot varieties, including Rubaru local shallot, for breeding programs focused on enhancing resilience and productivity in response to climate variability and pest pressures (Herlina *et al*., 2019).

Qualitative morphological traits, such as bulb flesh color, bulb shape, and skin thickness, had a high degree of uniformity, suggesting that the accessions shared a common ancestor (Rachmawati *et al*., 2023). However, significant differences existed between accession 2, with its pink bulb skin, and accession 6, where the maximum diameter was positioned in the middle. The variation could show local adaptations to specific environmental conditions, such as environmental stress, which have shaped the evolution of both accessions (Ackerly, 2012; Hussein *et al*., 2023).

PCA showed that three main components accounted for 80.92% of the data variance, offering a robust representation of morphological traits diversity. PC1, which explained 38.35% of the variance, was dominated by growth characteristics, such as the number of leaves, bulb count, flower age, and harvest age. PC2 (27.38%) was mainly associated with bulb size and weight, while PC3 (15.19%) showed tuber length and plant height. This information was valuable for identifying key traits to guide the selection and breeding of local shallot (Hasan *et al*., 2024). The results were in line with the observation of Abdi and Williams (2010), which showed the importance of PCA in reducing dimensionality while retaining critical information. The PCA results showed that important traits for Rubaru shallot included the number, size, and weight of the bulbs. However, consumer preference leaned away from small bulbs, which impacted the desirability of the product (Saadah, 2023). The strong aroma of Rubaru shallot also remained a distinct characteristic that attracted consumers.

Cluster analysis showed that accessions 2 and 5 had higher morphological similarity, showing possible genetic relationships. These relationships could be further examined through molecular methods such as SSR or RAPD analysis (Garcia *et al*., 2004; Hussein *et al*., 2023). The greater morphological variation observed in accessions 6 and 8, presented opportunities for future research on local adaptations, particularly in the context of climate change challenges.

Rubaru's local shallot showed considerable potential for breeding programs due to its rich diversity. The stability of certain traits made the commodity an excellent candidate for genetic selection. In contrast, variation in other traits offered avenues for enhancing adaptability to environmental changes. Incorporating molecular methods to identify genetic similarities could further complement this research and assist in developing superior varieties.

This research successfully identified and characterized morphological traits of the local shallot from Rubaru. The analysis results showed that key traits, such as the number of tubers, tuber weight, and number of leaves, contributed significantly to the total variability. Traits were captured by PC1 and PC2, which both accounted for 65.73% of the total variance. These traits showed potential for selection in breeding superior varieties.

The clustering of accessions based on morphological traits signified close genetic relationships between accessions 2 and 5. In contrast, accessions 6 and 8 showed greater variability, showing local adaptations to specific environmental conditions. This information was valuable for conserving genetic diversity and developing adaptive, superior varieties.

In conclusion, this research provided a strong foundation for Rubaru's local shallot breeding program, aiding in the selection of desirable traits and the preservation of genetic resources to address future agricultural challenges.

Acknowledgments

The authors would like to express their appreciation and gratitude to the Directorate of Research, Technology, and Community Service (DRTPM) of the Directorate General of Higher Education, Ministry of Education and Culture of the Republic of Indonesia, for the funding support provided through the Domestic Cooperation Research Grant with Contract number 109/E5/PG.02.00.PL/2024.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

Abdi, H. and Williams, L. J. (2010). Principal component analysis. Wiley Interdisciplinary Reviews: Computational Statistics, 2:433-459.

Anugrah, D. E., Marlin, M. and Sudjatmiko, S. (2024). Characterization of shallot morphology of salinity at lethal concentration 20 (LC20) and 50 (LC50). Jurnal Hortikultura Indonesia, 15:100-111.

Ackerly, D. D. (2012). Community Assembly , Niche Conservatism , and Adaptive Evolution in Changing Environments Author (s): David D . Ackerly Reviewed work (s): Source : International Journal of Plant Sciences , Vol . 164 , No . S3 , Evolution of Functional Traits in Plant. International Journal of Plant Sciences, 164:164-184. http://www.jstor.org/stable/10.1086/368401

Azam, M. G., Sarker, U., Hossain, M. A., Mahabubul Alam, A. K. M., Islam, M. R., Hossain, N. and Alamri, S. (2024). Phenotypic diversity in qualitative and quantitative traits for selection of high yield potential field pea genotypes. Scientific Reports, 14:1-24. https://doi.org/10.1038/s41598-024-69448-7

Beşirli, G. (2024). Evaluation of Turkish shallot genetic resources for morphological, biochemical and sensory properties. Turkish Journal of Agriculture and Forestry, 48:618-633.

Ceccarelli, S., Grando, S., Maatougui, M., Michael, M., Slash, M., Haghparast, R., Rahmanian, M., Taheri, A., Al-Yassin, A., Benbelkacem, A., Labdi, M., Mimoun, H. and Nachit, M. (2010). Plant breeding and climate changes. Journal of Agricultural Science, 148:627-637. https://doi.org/10.1017/S0021859610000651

Devy, N. F., Hardiyanto, H., Syah, J. A., Setyani, R. and Puspitasari, P. (2021). The effect of True Shallot Seed (TSS) varieties and population on growth and bulb yield. Indian Journal of Agricultural Research, 55:341-346.

Dewi, T., Yustika, R. D. and Arianti, F. D. (2024). Enhancement of production and food security through sustainable shallot cultivation. IOP Conference Series: Earth and Environmental Science, 1364.

Fitriana, N. and Susandarini, R. (2019). Morphology and taxonomic relationships of shallot (Allium cepa L. group aggregatum) cultivars from Indonesia. Biodiversitas, 20:2809-2814.

Garcia, A. A., Benchimol, L. L., Barbosa, A. M. ., Geraldi, I. O., Souza Jr, C. L. and de Souza, A. P. (2004). Comparation of RAPD, RFLP, AFLP and SSR markers for diversity studies in tropical maize inbred lines. Genetics and Molecular Biology, 27:579-588.

Ghahremani-Majd, H. and Dashti, F. (2014). Genetic diversity of Persian shallot (*Allium hirtifolium* Boiss.) populations based on morphological traits and RAPD markers. Plant Systematics and Evolution, 300:1021-1030.

Greenacre, M., Groenen, P. J. F., Hastie, T., d'Enza, A. I., Markos, A. and Tuzhilina, E. (2022). Principal component analysis. Nature Reviews Methods Primers, 2:100.

Hageman, J. A., Malosetti, M. and van Eeuwijk, F. A. (2012). Two-mode clustering of genotype by trait and genotype by environment data. Euphytica, 183:349-359.

Hasan, M. M., Mia, M. A. B., Ahmed, J. U., Karim, M. A., Islam, A. K. M. A. and Mohi-Ud-Din, M. (2024). Heat stress tolerance in wheat seedling: Clustering genotypes and identifying key traits using multivariate analysis. Heliyon, 10:e38623.

Herlina, L., Reflinur, Sobir, Maharijaya, A., Wiyono, S. and Istiaji, B. (2019). Genetic Diversity of Indonesian Shallots Based on Bulb-Tunic Patterns and Morphological Characters. Indonesian Journal of Agricultural Science, 20:19-28. https://doi.org/10.21082/ijas.v20n1.2019.p19-28

Hussein, M. A. A., Eid, M., Rahimi, M., Filimban, F. Z. and El-Moneim, D. A. (2023). Comparative Assessment of SSR and RAPD markers for genetic diversity in some Mango cultivars. PeerJ, 11:1-22.

IPGRI, ECP/GR, AVRDC. 2001. Descriptors for Allium (*Allium* spp.). International Plant Genetic Resources Institute, Rome, Italy; European Cooperative Programme for Crop Genetic Resources Networks (ECP/GR), Asian Vegetable Research and Development Center, Taiwan

Maharijaya, A., Kurnianingtyas, D., Sobir, Wiyono, S. and Purwito, A. (2023). Possible morphological and chemical resistance mechanism of shallots (*Allium cepa* var ascalonicum) to *Colletotrichum gloeosporioides* Penz. Sabrao Journal of Breeding and Genetics, 55:541-549.

Major, N., Goreta Ban, S., Urlić, B., Ban, D., Dumičić, G. and Perković, J. (2018). Morphological and biochemical diversity of shallot landraces preserved along the Croatian coast. Frontiers in Plant Science, 9.

Maulidha, A. R., Maharijaya, A., Purwito, A. and Sobir. (2024). Shallot (*Allium cepa* var. aggregatum) genotypes and their crossbreds resistance to fusarium wilt disease. Sabrao Journal of Breeding and Genetics, 56:180-191.

Naktuinbouw. 2010. Naktuinbouw Calibration Book: *Allium cepa* (Cepa group), *Allium cepa* (Aggregatum group), *Allium oschaninii* O, Fedtsch and hybrids between them, Onion, Echalion, Shallot, Grey Shallot. Version 1. Naktuinbouw, Nederland.

Placide, R., Shimelis, H., Laing, M. and Gahakwa, D. (2015). Application of principal component analysis to yield and yield related traits to identify sweet potato breeding parents. Tropical Agriculture, 92:1-15.

Pratiwi, E. E., Maharijaya, A. and Dinarti, D. (2020). Genetic diversity of shallot (*Allium cepa* var. aggregatum) based on morphology and molecular markersetik bawang merah (*Allium cepa* var. aggregatum) Berdasarkan Marka Morfologi dan Molekuler. Jurnal Hortikultura Indonesia, 11:51-60.

Rachmawati, D., Aisyawati, L., Latifah, E., Sandrakirana, R. and Baswarsiati. (2023). The potential and characteristics of genetic resources of 7 national superior of shallots varieties in Indonesia. IOP Conference Series: Earth and Environmental Science, 1246:0-11.

Ramadhani, F., Surmaini, E., Dariah, A., Apriyana, Y., Estiningtyas, W., Susanti, E., Yustika, R. D., Sarvina, Y., Fanggidae, Y. R. and Nurjaya, N. (2024). Multisource spatiotemporal analysis of cropping patterns on dry upland: A case study in Rubaru Sub-district, Sumenep Regency. Egyptian Journal of Remote Sensing and Space Science, 27:403-415.

Saadah, I. R., Korlina, E., Waluyo, N., Sulastrini, I., Gunaeni, N., Pinilih, J. and Karjadi, A. K. (2023). Growth and response of several shallot varieties to its important diseases in Lembang highlands. IOP Conference Series: Earth and Environmental Science, 1287(1). https://doi.org/10.1088/1755-1315/1287/1/012019

Sari, V., Miftahudin. amd Sobir, D. (2017). Keragaman genetik bawang merah (*Allium cepa* L.) berdasarkan marka morfologi dan ISSR. Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy), 45:175-181.

Tabor, G., Mengistu, F. G. and Atinafu, G. (2024). Morphological characterization of shallot (Allium cepa L. var. aggregatum) segregating populations obtained from natural-outcrossing in Ethiopial-outcrossing in Ethiopia. International Journal of Horticultural Science, 76:74-83.

Triharyanto, E., Syamsiyah, J., Nyoto, S. and Wardyani, E. A. L. (2020). Phosphate solubilizing bacteria application to lowland shallot varieties cultivated in highland. IOP Conference Series: Earth and Environmental Science, 423:0-6.

Yofananda, O., Sobir, Wijaya, C. H. and Lioe, H. N. (2021). Variability and relationship of six Indonesian shallots (*Allium cepa* var. ascalonicum) cultivars based on amino acid profiles and fried shallot's sensory characteristics. Biodiversitas, 22:3327-3332.

(Received: 30 November 2024, Revised: 2 August 2025, Accepted: 26 August 2025)