Adv. Hort. Sci., 2025 39(4): 293-303
DOI: 10.36253/ahsc-18383
https://oaj.fupress.net/index.php/ahs

AHS
Advances in Horticultural Science

Optimal storage duration for dormancy break and early growth in shallot bulbs

C. Cennawati [1], **M. Faried** [2, (*)], **E. Syam'un** [2], **R.W. Putri** [3], **P. Wijaya** [4]

[1] *Muhammadiyah Enrekang University, Faculty of Science and Technology, Agrotechnology Program, Makassar, South Sulawesi, Indonesia.*
[2] *Hasanuddin University, Faculty of Agriculture, Agrotechnology Study Program, Makassar, South Sulawesi, Indonesia.*
[3] *West Sulawesi University, Faculty of Agriculture and Forestry, Agroecotechnology Program, Majene, West Sulawesi, Indonesia.*
[4] *Lambung Mangkurat University, Agroecotechnology Program, Agriculture Faculty, Banjarbaru, Indonesia.*

(*) **Corresponding author:**
muhfaried@agri.unhas.ac.id

Citation:
CENNAWATI C., FARIED M., SYAM'UN E., PUTRI R.W., WIJAYA P., 2025 - *Optimal storage duration for dormancy break and early growth in shallots bulb.* - Adv. Hort. Sci., 39(4): 293-303.

ORCID:
CC: 0000-0003-4949-4016
FM: 0000-0001-6326-1724
SE: 0000-0001-5875-118X
PRW: 0000-0003-1591-668X
WP: 0009-0003-0604-4100

Data Availability Statement:
All relevant data are within the paper and its Supporting Information files.

Competing Interests:
The authors declare no conflict of interests.

Received for publication 2 August 2025
Accepted for publication 12 November 2025

Key words: Dormancy, shallot, sprouting, storage duration.

Abstract: Shallots (*Allium ascalonicum* L.) are a critical horticultural crop in Indonesia; however, their production remains unstable owing to the inconsistent availability of quality planting materials. This study aimed to determine the optimal storage duration to break dormancy and enhance the early growth of Super Philips shallot bulbs under ambient conditions. A randomised complete block design was used to assess five storage durations (2, 4, 6, 8, and 10 weeks) by evaluating the sprouting percentage, rooting percentage, time to emergence, and early vegetative traits, including root volume, root length, plant height, and number of leaves. The results showed that bulbs stored for eight weeks exhibited the highest sprouting (98%) and rooting (99%) rates, along with the shortest mean emergence times and superior vegetative growth. Statistical analyses confirmed strong correlations and predictive regressions linking storage duration and physiological performance. These findings indicate that an eight-week storage period provides optimal physiological conditions for dormancy release, improves seedling vigour, and supports synchronised root and shoot development. This study offers actionable insights for seed management practices and validates empirical storage traditions, with implications for more stable and productive cultivation systems.

1. Introduction

Shallot (*Allium ascalonicum* L.) is one of Indonesia's most vital horticultural commodities and holds significant national economic value due to its indispensable role in daily cuisine. Used ubiquitously across households and the food industry, its irreplaceable culinary function underscores its strategic agricultural status. Beyond its role as a kitchen staple, shallots offer substantial nutritional and medicinal properties. They contain essential macronutrients and micronutrients, such as carbohydrates, proteins, and minerals including calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), and zinc (Zn). Additionally, shallots are rich in bioactive compounds like phenols, flavonoids, and antioxidants, which possess powerful free radical-scavenging activities (Adeyemo *et al*., 2023). The growing population and the expanding food processing sector in Indonesia further drive the consistent increase in demand for shallots.

Despite the growing need, shallot production remains volatile. A persistent imbalance between supply and demand contributes to market instability and price inflation. For example, in April 2024, shallots contributed the highest food inflation rate of 30.75% month-to-month due to reduced availability across regions (Liman, 2024). Per capita consumption of shallots rose from 2.802 kg/year in 2019 to 2.861 kg/year in 2023 (Central Bureau of Statistics of Indonesia, 2024). However, national shallot production has shown fluctuations: 2,004,590 tons in 2021, decreasing to 1,982,360 tons in 2022, and slightly increasing to 1,985,233 tons in 2023 (Central Bureau of Statistics of Indonesia, 2024). This instability is attributed to multiple agronomic and logistical constraints, notably the inconsistent availability of high-quality planting materials.

One major constraint in shallot cultivation is the dependency on bulbs as the primary planting material. These bulbs serve as the foundation for initial plant growth and significantly affect crop productivity. However, their use is complicated by the natural dormancy phase post-harvest, which hinders immediate replanting (Arif *et al*., 2022). Consequently, bulbs require storage to allow dormancy to break before planting. This storage period, while necessary, introduces a new challenge: quality deterioration. Improper storage conditions can compromise bulb viability and vigor, resulting in suboptimal germination and plant development (Syam'un *et al*., 2017). Typically, shallot bulbs are stored for 3 to 4 months post-harvest to overcome dormancy (Nurfaida *et al*., 2024). Yet, extended or poorly managed storage can lead to reduced sprouting rates, delayed emergence, weight loss, and lower dry matter accumulation (Ansar *et al*., 2022).

The general solution employed by farmers involves storing the bulbs under ambient conditions until dormancy subsides. However, this common practice lacks standardization and often depends on empirical tradition rather than scientific guidance. Variables such as bulb variety, pre- and post-harvest conditions, and storage environment (temperature, humidity, and airflow) heavily influence the dormancy period and the outcome of sprouting and rooting. Deviations in these parameters can result in mechanical, physiological, or microbial damage. Typical manifestations include moisture loss, abnormal sprouting and rooting, softening, and fungal decay (Maemunah *et al*., 2015; Ayu *et al*., 2023). These issues pose serious risks to planting efficiency and yield.

Scientific studies have attempted to identify optimal storage conditions and durations to manage bulb dormancy. Tarigan *et al.* (2019) reported that two months of storage influenced the prevalence of diseases caused by pathogens such as *Peronospora destructor*, *Alternaria porri*, and *Fusarium* spp. Kusmali *et al.* (2020) found that shallot bulbs stored for 16 weeks exhibited significant quality decline, with 32% rot and a weight loss of 38.7%. Meanwhile, Sarjani *et al.* (2018) observed that dormancy in shallots ends after approximately 12 weeks at 5°C, with sprouting viability and vigor exceeding 90% and a relatively low damage rate (9.8%). Such findings highlight that both the duration and condition of storage are crucial to maintaining bulb quality and performance.

Despite these insights, many farmers in regions like Enrekang Regency in South Sulawesi continue to rely on traditional practices, commonly storing shallot bulbs for approximately two months by hanging them at room temperature. Although this method is widely used, it lacks scientific validation and fails to account for environmental variability and physiological responses of different varieties. Therefore, refining the storage duration to match the physiological needs of the crop under local conditions could improve dormancy management, seed quality, and ultimately productivity.

Recent investigations into physiological changes during dormancy offer deeper insights into dormancy break mechanisms. Sarjani *et al.* (2018) emphasized that hormonal shifts-specifically increases in gibberellins, auxins, and cytokinins are instrumental in initiating sprouting, counteracting inhibitory effects of abscisic acid. Similarly, Sohany *et al.* (2016)

demonstrated that storing bulbs for 60 days at 13°C resulted in 68% sprouting. Pasigai *et al.* (2016) stated that two months of storage at room temperature is generally adequate to break dormancy in many shallot varieties. These studies underscore the interplay between environmental stimuli and internal biochemical changes in bulbs during storage, suggesting the possibility of identifying a critical storage period that maximizes seedling vigor while minimizing losses.

While existing research provides foundational knowledge on dormancy and sprouting behavior in shallots, comprehensive studies tailored to specific varieties and regional contexts remain limited. In particular, there is a lack of detailed assessments of the Super Philips variety a cultivar commonly used by farmers in Enrekang. The current literature has yet to fully quantify how different storage durations under practical room conditions affect physiological responses such as sprouting rate, rooting success, and early vegetative growth in this variety. Addressing this gap is essential for evidence-based agronomic recommendations that align with local practices and ecological conditions.

Therefore, this study aims to determine the optimal storage duration of Super Philips shallot bulbs to effectively break dormancy and enhance early seedling performance under ambient storage conditions. By evaluating key parameters such as sprouting percentage, rooting time, root and shoot development, and correlating them with storage periods, this research offers a practical solution grounded in physiological evidence. The novelty of this work lies in its focus on a locally important cultivar, its use of ambient storage mirroring field conditions, and its systematic assessment of multiple physiological parameters. The study provides actionable recommendations that can improve seed management, reduce crop failure, and contribute to more stable shallot production.

2. Materials and Methods

Study location and duration

This study was conducted at the Greenhouse of the Agrotechnology Department, Faculty of Science and Technology, Muhammadiyah University of Enrekang, located in South Sulawesi, Indonesia. The experiment took place between December 2024 and March 2025, encompassing the entire period from post-harvest bulb storage to the early growth stages of the shallot seedlings. The environmental conditions during the study closely reflected typical ambient storage and cultivation conditions in the region, thus ensuring the relevance and applicability of the results to local agricultural practices.

Plant material and bulb harvesting

The plant material used in this research was the Super Philips variety of shallot (*Allium ascalonicum L.*), a cultivar widely cultivated by farmers in the Enrekang region due to its favorable agronomic traits and market demand. The bulbs were harvested on 10 December 2024 from a shallot field located in Bulo Village, Bungin Subdistrict, Enrekang Regency. Bulbs selected for the study were uniform in size, free from visible defects, and representative of healthy post-harvest quality to reduce variability due to initial physiological differences.

Storage conditions and duration treatments

Immediately following harvest, shallot bulbs were subjected to five different storage durations under ambient room temperature conditions, which ranged between 20 and 30°C, with an average relative humidity of approximately 60%. The bulbs were stored in mesh containers to allow for sufficient air circulation and to prevent moisture accumulation, which could otherwise promote microbial growth. During the storage period, regular inspections were conducted to identify and discard any bulbs showing signs of rotting, fungal infection, or physical damage. The storage duration treatments were set at 2, 4, 6, 8, and 10 weeks, labeled respectively as P1, P2, P3, P4, and P5. These durations were chosen to reflect commonly observed storage periods in traditional farming practices while enabling an analytical comparison of physiological outcomes.

Experimental design

The experiment was arranged in a one-factor Randomized Complete Block Design (RCBD) to control for potential variability in greenhouse microclimate and ensure the statistical robustness of treatment comparisons. The single experimental factor was storage duration, with five treatment levels as described above. Each treatment was replicated four times, resulting in 20 experimental units. Within each unit, bulbs were planted and monitored under standardized agronomic practices to isolate the effect of storage duration.

Cultivation practices

After completing their respective storage durations, the shallot bulbs were transplanted into greenhouse beds. The planting dates corresponded to each storage treatment: bulbs in P1 were planted on 24 December 2024, P2 on 7 January 2025, P3 on 21 January 2025, P4 on 4 February 2025, and P5 on 18 February 2025. Soil preparation included tilling, weed removal, and application of organic fertilizers. Additionally, poultry manure was incorporated as an organic amendment to enhance soil fertility and structure. Standard cultivation procedures such as irrigation, manual weeding, pest and disease monitoring, and thinning were performed uniformly to maintain plant health and minimize the influence of external variables on seedling performance.

Observed parameters

To assess the impact of storage duration on dormancy break and early seedling growth, various physiological and morphological parameters were observed. These included sprouting metrics such as the percentage of bulb sprouting (%), the time taken to reach 10% sprouting (d), and the mean sprouting time (d). Rooting performance was evaluated by measuring the percentage of bulbs that developed roots (%), the time to reach 10% rooting (d), and the mean rooting time (d). Furthermore, vegetative growth parameters including root volume (mm³), root length (cm), plant height (cm), and number of leaves per plant were recorded. Data collection commenced immediately after planting and continued through the early stages of vegetative development to capture reliable indicators of bulb vigor and physiological response to storage duration.

Statistical analysis

The data obtained were processed and analyzed using R Studio statistical software. A one-way analysis of variance (ANOVA) was employed to test the effects of different storage durations on each observed parameter. The level of significance was set at α = 0.05. Where significant differences were detected, post-hoc analysis was conducted using Duncan's Multiple Range Test (DMRT) to compare treatment means. Regression analysis was also conducted to evaluate the linear relationships between storage duration and each physiological response. Coefficients of determination (R^2) were reported to indicate the strength of association, and the regression equations were used to model predictive responses. In addition, correlation analysis was performed to determine the relationships among all measured parameters, particularly focusing on the interactions between sprouting, rooting, and vegetative traits. The analysis was carried out in the latest version of R Studio using the cor() function with the Pearson method, and the absolute correlation coefficients (|r|) were obtained by applying the abs() function to the resulting correlation matrix to evaluate the strength of association irrespective of direction. The strength of correlations was interpreted based on |r| values, where <0.3 indicated a weak, 0.3-0.7 a moderate, and >0.7 a strong relationship. To visualize the overall interrelationships among parameters, a correlation web was constructed using the qgraph and corrplot packages in R Studio, with edge thickness representing the magnitude of |r| and color gradients (blue to pink) indicating the direction of the correlations.

3. Results

Effect of storage duration on bulb sprouting

The results of this study demonstrate that storage duration significantly influenced the sprouting capacity of Super Philips shallot bulbs (Fig. 1). Bulbs stored for eight weeks exhibited the highest sprouting percentage at 98%, which was statistically different ($p<0.05$) from all other treatments. In

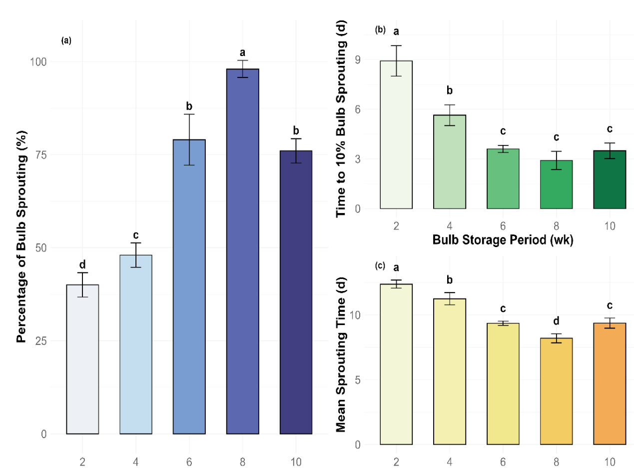

Fig. 1 - Sprouting traits. Note: Week (wk). Bars represent mean values (± standard error, n = 3). Different lowercase letters above bars indicate significant differences among storage durations according to Duncan's Multiple Range Test ($p<0.05$).

contrast, the lowest sprouting percentage was recorded in the two-week storage treatment (40%), followed by four weeks (48%), six weeks (79%), and ten weeks (76%). These findings indicate that an eight-week storage period is optimal for promoting dormancy break and achieving maximum sprouting efficiency.

The time required to reach 10% sprouting (T10S) also varied significantly across treatments. Bulbs stored for eight weeks reached this threshold in just 2.91 days, which was statistically different ($p < 0.05$) from all other treatments. Although storage durations of six and ten weeks (3.1 and 3.3 days, respectively) were not statistically different from the eight-week treatment, the shortest duration was consistently achieved with eight-week storage. This result supports the hypothesis that dormancy break is most effectively initiated around this period. Furthermore, the mean bulb sprouting time (MBS) reinforced this trend. Bulbs stored for eight weeks recorded the shortest MBS at 6.7 days, which was significantly shorter than the values for two weeks (10.8 days), four weeks (9.4 days), six weeks (7.7 days), and ten weeks (7.8 days). This pattern confirms that eight weeks of storage not only maximized the percentage of sprouting but also accelerated the initiation and uniformity of sprout emergence.

Effect of storage duration on bulb rooting

Storage duration also had a significant impact on the rooting response of shallot bulbs (Fig. 2). The highest percentage of bulb rooting (99%) was observed in the eight-week storage treatment, significantly outperforming all other treatments. Rooting percentages for the remaining durations were as follows: two weeks (48%), four weeks (77%), six weeks (92%), and ten weeks (92%). Like the sprouting results, these data suggest that an eight-week storage duration supports optimal physiological readiness for root initiation.

In terms of the time to reach 10% rooting (T10R), bulbs stored for eight weeks demonstrated the fastest performance at 1.54 days. This was significantly different from the two-week (5.20 days), four-week (2.99 days), and ten-week (2.78 days) treatments. Although the six-week treatment (1.98 days) did not differ significantly from the eight-week treatment, the consistent superiority of the eight-week period in both sprouting and rooting metrics confirms its central role in dormancy termination.

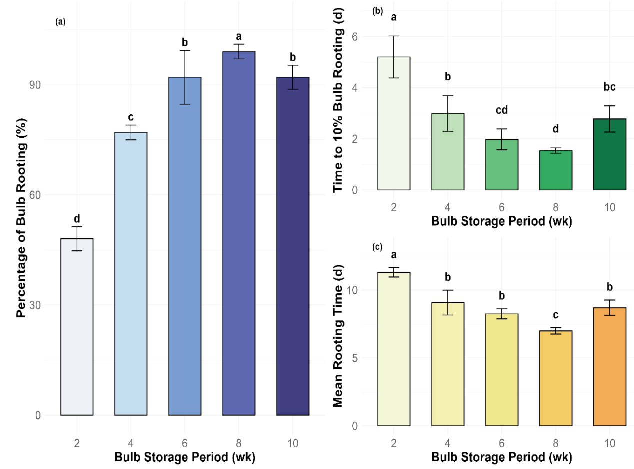

Fig. 2- Rooting traits. Note: Week (wk). Bars represent mean values (± standard error, n = 3). Different lowercase letters above bars indicate significant differences among storage durations according to Duncan's Multiple Range Test ($p<0.05$).

The mean bulb rooting time (MBR) further emphasized these differences. The shortest MBR was found in the eight-week treatment at 6.9 days, followed by six weeks (8.24 days), ten weeks (8.69 days), four weeks (9.07 days), and two weeks (11.30 days). These results highlight the advantage of storing bulbs for eight weeks to achieve faster and more synchronized rooting responses, thereby improving early seedling vigor.

Relationship between sprouting and rooting dynamics

Interestingly, the study revealed that rooting does not necessarily precede or guarantee sprouting. Across all treatments, the percentage of rooted bulbs consistently exceeded the percentage of sprouted bulbs (Fig. 3). However, the smallest discrepancy between these two indicators was recorded in the eight-week storage treatment, suggesting improved synchronization of root and shoot development at this stage of storage.

This asynchronous behavior implies that root emergence may serve as an earlier physiological marker of dormancy break, with sprouting following shortly thereafter. These findings align with the observations of Nurfaida *et al.* (2024), who noted that while rooting may begin before visible sprouting, the concurrent occurrence of both phenomena marks the end of the dormancy phase.

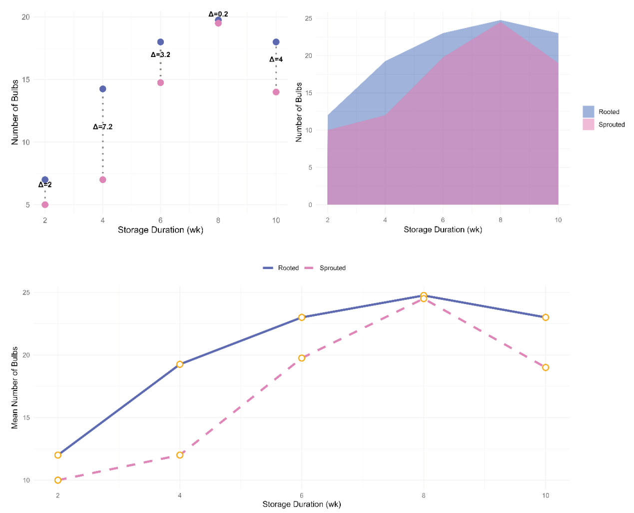

Fig. 3 - Sprouting traits. Note: Week (wk). The symbol Δ (delta) represents the difference between the number of bulbs that produced roots and those that initiated shoot sprouting.

Vegetative growth performance

Storage duration significantly affected all observed vegetative growth parameters, including plant height, number of leaves, root volume, and root length (Fig. 4). The most robust vegetative growth was observed in the eight-week treatment. Plants derived from bulbs stored for eight weeks attained an average height of 19.12 cm, significantly greater than those from two weeks (8.18 cm), four weeks (12.18 cm), six weeks (14.80 cm), and ten weeks (16.10 cm) treatments.

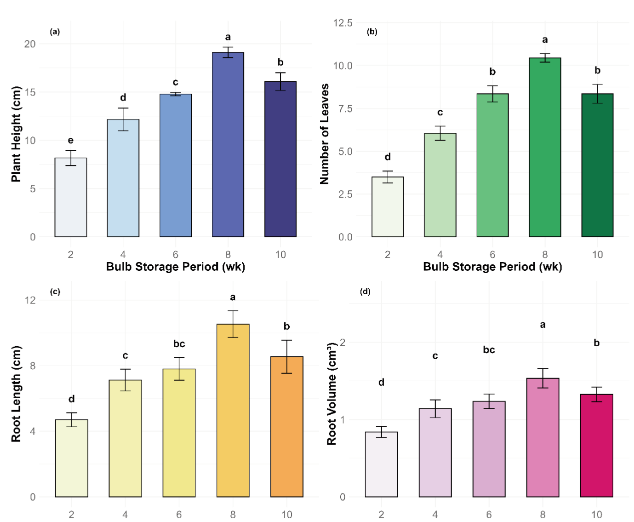

Fig. 4 - Morphology traits. Note: Week (wk). Bars represent mean values (± standard error, n = 3). Different lowercase letters above bars indicate significant differences among storage durations according to Duncan's Multiple Range Test ($p<0.05$).

Similarly, the number of leaves was highest in the eight-week treatment (10.45 leaves per plant), statistically surpassing the other treatments, which recorded the following averages: two weeks (3.5), four weeks (6.05), six weeks (8.35), and ten weeks (8.35). These results underscore the direct influence of optimal storage duration on above-ground vegetative development.

Below-ground traits exhibited the same trend. The highest root volume was recorded in the eight-week treatment at 1.54 mm^3, while the lowest was seen in the two-week treatment (0.84 mm^3). Intermediate values were recorded for four weeks (1.14 mm^3), six weeks (1.24 mm^3), and ten weeks (1.33 mm^3). Likewise, the longest root length (10.53 cm) was observed in the eight-week treatment, compared to 4.70 cm (two weeks), 7.13 cm (four weeks), 7.80 cm (six weeks), and 8.55 cm (ten weeks). These findings indicate that an eight-week storage period enhances the early vigor and morphological development of shallot seedlings, confirming its importance in postharvest management practices.

Correlation analysis of growth parameters

Pearson correlation analysis revealed strong and statistically significant relationships among most of the measured parameters (Fig. 5). The percentage of bulb sprouting (PBS) showed a strong negative correlation with mean sprouting time (MST, r = -0.96), time to 10% sprouting (T10S, r = -0.86), and mean rooting time (MRT, r = -0.83). This suggests that bulbs with a higher sprouting percentage tended to sprout and root earlier and more uniformly. PBS also had strong positive correlations with vegetative growth parameters, including root volume (RV, r = 0.89), root length (RL, r = 0.90), number of leaves (NOL, r = 0.97), and plant height (PH, r = 0.94), indicating a clear linkage between sprouting success and early vigor.

The time to 10% sprouting (T10S) was negatively correlated with most vegetative parameters, including RV (r = -0.85), RL (r = -0.85), NOL (r = -0.93), and PH (r = -0.91). Similar trends were observed for MST and MRT, both showing strong negative associations with early growth metrics such as NOL (r = -0.97 and -0.91, respectively) and PH (r = -0.96 and -0.91, respectively), indicating that slower sprouting and rooting were consistently associated with reduced growth performance. The percentage of bulbs rooted (PBR) also exhibited positive

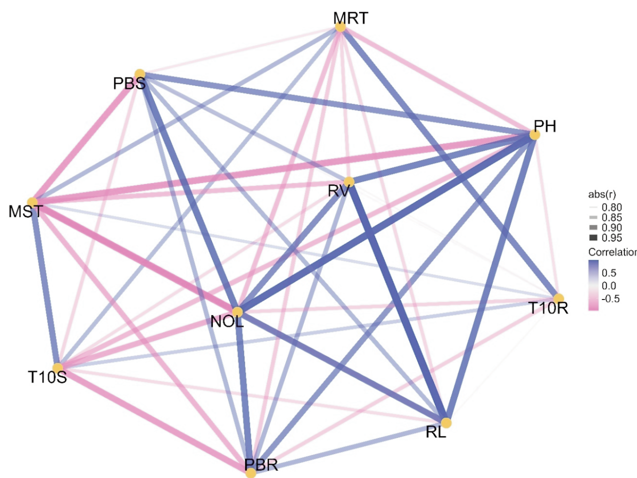

Fig. 5 - Correlation web. Note: percentage of bulb sprouting (PBS), time to 10% sprouting (T10S), mean sprouting time (MST), percentage of bulb rooting (PBR), time to 10% rooting (T10R), mean rooting time (MRT), root volume (RV), root length (RL), plant height (PH), and number of leaves (NOL).

correlations with RV (r = 0.90), RL (r = 0.90), NOL (r = 0.96), and PH (r = 0.94), reinforcing the importance of rapid and uniform root development in promoting aboveground growth. Notably, NOL and PH were highly correlated (r = 0.98).

Regression analysis

Regression models further illustrated the relationship between storage duration and key physiological parameters (Fig. 6). The regression equation for the percentage of bulb sprouting was y = 11.2 + 6.1x, with a coefficient of determination (R^2) of 0.64, indicating that 64% of the variation in sprouting percentage could be explained by storage duration. For the time to reach 10% sprouting, the regression equation was y = 7.11 − 0.486x (R^2 = 0.59), and for mean sprouting time, y = 11.2 − 0.443 x (R^2 = 0.62). These negative slopes suggest that longer storage durations generally result in faster sprouting responses.

Similarly, for the percentage of bulb rooting, the regression equation was y = 28.6 + 5.5x with R^2 = 0.70, while for time to 10% rooting, y = 3.86 − 0.227x (R^2 = 0.38), and mean rooting time, y = 9.07 − 0.32x (R^2 = 0.37). These values reinforce the previous findings, showing a strong linear influence of storage duration on both rooting and sprouting dynamics. The regression for root volume was y = 0.805 + 0.0683x (R^2 = 0.62), while root length followed y = 4.41 + 0.555x (R^2 = 0.61). Number of leaves was best

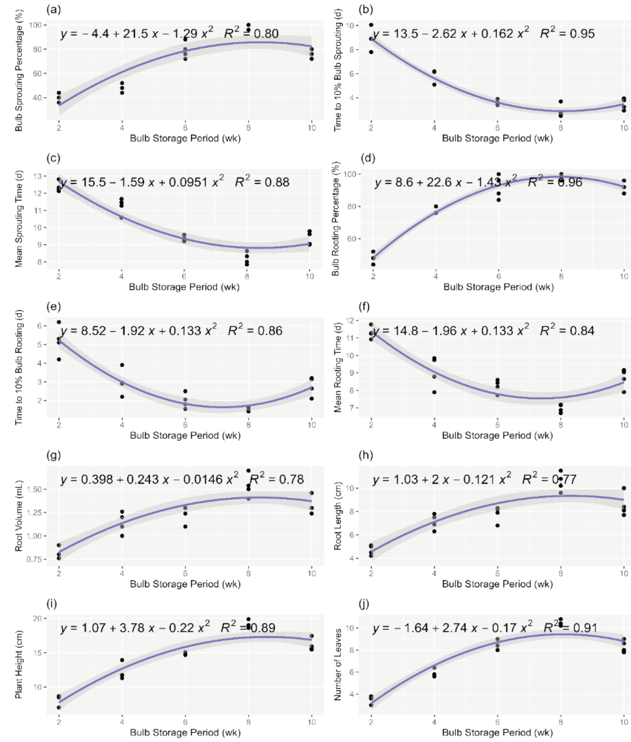

Fig. 6 - Regression analysis. Note: Week (wk). Black dots represent observed values. The blue line indicates the fitted quadratic regression model for each variable, while the grey shaded band represents the 95% confidence interval of the fitted line, illustrating the uncertainty around the model-estimated mean response.

described by the equation y = 3.11 + 0.705x (R^2 = 0.69), and plant height followed y = 7.24 + 1.14x (R^2 = 0.73), indicating a strong predictive relationship with storage duration. These models confirm that an eight-week storage duration corresponds to the inflection point for optimal growth. In summary, the results of this study consistently show that storing shallot bulbs for eight weeks prior to planting produces the best outcomes across all major physiological indicators. This storage period not only accelerates and synchronizes the processes of sprouting and rooting but also enhances early vegetative growth. The convergence of results from statistical tests, correlation matrices, and regression models provides robust evidence supporting eight weeks as the ideal duration for pre-planting bulb storage in Super Philips shallots.

4. Discussion and Conclusions

The results of this study demonstrate that storage duration significantly affects the dormancy status, sprouting behaviour, and early vegetative growth of Super Philips shallot bulbs. Among the tested durations, an eight-week storage period consistently produced the best outcomes in terms of sprouting and rooting percentages, as well as subsequent shoot and root development. These findings align with earlier research that identifies storage time as a critical factor influencing physiological readiness and viability of shallot bulbs (Pasigai *et al.*, 2016; Sarjani *et al.*, 2018). The enhanced sprouting and rooting performance observed at eight weeks can be attributed to the natural progression of dormancy release. Dormancy in shallot bulbs is governed by a complex interplay of hormonal and environmental factors. As the storage period progresses, inhibitory compounds such as abscisic acid (ABA) gradually decline, while promotive hormones like gibberellins (GA), cytokinins, and auxins increase. This pattern is supported by evidence in onion bulbs showing that ABA concentration consistently declines during storage across cultivars and storage conditions (Chope *et al*., 2007 a; Chope and Terry, 2008), with the greatest reduction reported during the first 80 days of storage (Chope *et al.*, 2006). A pronounced decrease has also been observed between harvest and early storage, likely due to curing effects (Chope *et al*., 2007 b). Sarjani *et al.* (2018) reported that these hormonal shifts are critical for triggering metabolic activities required for sprouting. In the present study, the peak physiological response at eight weeks suggests that this duration coincides with a hormonal balance conducive to rapid shoot and root emergence. In addition to hormonal regulation, dormancy termination and sprouting onset are also marked by shifts in carbohydrate metabolism, including decreases in sucrose levels accompanied by increased respiration rate and enzyme activity (Benkeblia *et al.*, 2005; Abrameto *et al*., 2010).

Moreover, the acceleration of sprouting and rooting processes observed in the eight-week treatment can also be linked to favourable environmental storage conditions. The storage environment, characterized by room temperatures ranging from 20 to 30°C and relative humidity of approximately 60%, likely supported biochemical transitions necessary for dormancy break. Sohany *et al*. (2016) observed that shallot bulbs stored for 60 days at 13°C exhibited a 68% sprouting rate, supporting the hypothesis that controlled storage environments can enhance physiological performance. The higher percentages of both sprouting and rooting observed in the eight-week treatment confirm that this duration effectively breaks dormancy and enhances bulb viability. Root growth generally occurs before shoot emergence in dormant bulbs, as root initiation requires different hormonal activation than shoot development (Dubrovsky *et al*., 2008). This sequence may reflect the transition of the bulb from a sink organ to a source organ, which is necessary to sustain cell division at the meristematic tissue of the basal plate where rooting is initiated (Chope *et al.*, 2012 a; Chope *et al*., 2012 b). However, for optimal field performance, synchronized development of roots and shoots is crucial. The smaller discrepancy between rooting and sprouting percentages at eight weeks indicates improved physiological synchronization, which enhances transplant success and early growth (Nurfaida *et al*., 2024).

In contrast, the reduced performance in the two- and four-week storage treatments likely results from incomplete dormancy release. At these stages, inhibitory hormones may still be present in significant concentrations, delaying the onset of sprouting and reducing rooting activity. Ansar *et al.* (2022) emphasized that insufficient storage durations negatively affect vigour and lead to non-uniform seedling emergence. Similarly, the relatively moderate improvements seen at six and ten weeks suggest that eight weeks represents an optimal physiological threshold, beyond which bulb quality begins to decline. The decrease in physiological performance observed in the ten-week treatment may be attributed to the onset of senescence and cumulative exposure to storage-related stressors. Over time, stored bulbs are prone to water loss, nutrient depletion, and susceptibility to mechanical damage or microbial attack (Maemunah *et al.*, 2015; Ayu *et al*., 2023). Kusmali *et al.* (2020) found that bulbs stored for 16 weeks exhibited a 32% damage rate and 38.7% weight loss, indicating a decline in quality due to prolonged storage. The diminishing returns in sprouting, rooting, and vegetative traits observed in the ten-week treatment in this study support this conclusion.

In terms of vegetative performance, plants from eight-week stored bulbs exhibited superior shoot height, leaf number, root length, and root volume. These indicators are commonly associated with higher seedling vigour and better adaptation to field conditions. Lestari *et al.* (2018) noted that high-vigour bulbs tend to produce uniform and robust seedlings, while low-vigour bulbs generate weaker and less consistent growth. The clear advantage of the eight-week treatment across all vegetative parameters highlights the importance of aligning storage practices with physiological readiness to maximize seedling quality. Regression and correlation analyses further validated these findings. The strong linear relationship between storage duration and sprouting/rooting percentages, as well as plant height and leaf number, indicates that physiological responses are predictably linked to storage time. For example, the coefficient of determination (R^2) for plant height was 0.73, suggesting that 73% of the variation in shoot growth could be explained by storage duration. This statistical robustness provides practical implications for farmers and seed producers aiming to optimize bulb performance.

The synchronization between root and shoot development observed at eight weeks is particularly noteworthy. Root development is essential for water and nutrient uptake, while shoot emergence facilitates photosynthesis and energy production. Enhanced coordination of these two processes ensures better establishment after transplanting and contributes to overall crop productivity (Leskovar and Othman, 2021). Synchronized sprouting ensures more uniform plant development, minimizing competition for light, water, and nutrients among individuals, which can ultimately contribute to improved plant health and higher yields (Kimmelshue *et al.*, 2022; McDonald *et al.*, 2024). The concurrent increase in root length and volume with plant height and leaf number suggests that dormancy break not only initiates sprouting but also prepares the entire plant system for active growth. Another critical insight from this study is the differential timing of physiological events. While rooting may occur earlier than sprouting in many treatments, true dormancy break is marked by the emergence of both roots and shoots. This observation aligns with the findings of Nurfaida *et al.* (2024), who emphasized that dormancy termination should be assessed through a combination of rooting and sprouting metrics. The practical implication is that seed quality assessments should include both parameters rather than rely solely on sprouting percentages.

The findings also validate the traditional practice in Enrekang Regency, where farmers typically store shallot bulbs for approximately two months before planting. Although largely empirical, this practice closely corresponds with the optimal storage duration identified in the present study. By quantifying the physiological advantages associated with eight-week storage, this research provides an evidence-based framework to support and refine local knowledge, thereby strengthening the link between scientific evidence and farmer-based management practices. Supporting this concept, evidence from other bulbous ornamentals such as lilies and tulips indicates that dormancy release and subsequent growth are also promoted by an optimum storage period (e.g., 6-8 weeks under cold storage), emphasizing that dormancy termination in bulb crops often occurs within a defined physiological window rather than increasing indefinitely with longer storage (Yang *et al.*, 2015 a; Yang *et al.*, 2015 b). However, despite the strong evidence supporting the benefits of eight-week storage, the influence of cultivar specificity and environmental variability should be carefully considered. Different shallot cultivars may exhibit distinct dormancy behaviours and physiological thresholds. Moreover, fluctuations in storage temperature, relative humidity, and light exposure may modify hormonal regulation and influence dormancy progression. Therefore, site-specific validation and cultivar-based comparisons are required to confirm the broader applicability of these findings across diverse production environments.

Finally, although this study focused on early physiological responses, future research should explore the long-term effects of storage duration on crop yield, bulb size, and postharvest quality. Integrating physiological assessments with yield-based outcomes will provide a comprehensive understanding of how pre-planting storage influences the entire growth cycle and commercial viability of shallot crops.

This study demonstrates that storage duration plays a critical role in the dormancy release and early vegetative performance of Super Philips shallot bulbs. Among the five evaluated durations, eight weeks of ambient storage consistently resulted in the highest sprouting and rooting percentages, fastest emergence times, and the most vigorous seedling development in terms of root volume, root length, plant height, and number of leaves. These findings suggest that an eight-week period aligns with optimal physiological readiness, supported by hormonal transitions favorable for growth. The observed synchronization between sprouting and rooting, as well as the strong correlations with vegetative traits, indicate a compounded benefit for crop establishment. This study contributes empirical validation to traditional practices, reinforces the importance of pre-planting storage management, and enhances the broader understanding of dormancy physiology in shallots. Future research should explore the long-term impacts of storage duration on yield and postharvest quality, as well as varietal responses across diverse agroecological zones.

Acknowledgements

The authors express their sincere gratitude to the Agrotechnology Program for providing the necessary facilities and support for this research. We also extend our appreciation to colleagues and technical staff for their valuable assistance.

The authors used the Paperpal by Editage tool (https://paperpal.com/) during the preparation of this manuscript with the aim of improving clarity and language quality. After using this tool/service, the authors reviewed and edited the content as necessary and took full responsibility for the final content of the published article.

References

ABRAMETO M.A., POZZO ARDIZZI C.M., GIL M.I., MOLINA L.M., 2010 - *Analysis of methodologies for the study of composition and biochemical carbohydrate changes in harvest and postharvest onion bulbs*. - Phyton-Inter. J. Exp. Bot., 79: 123-132.

ABUBAKAR M.S., MADUAKO J.N., AHMAD M., 2019 - *Effects of storage duration and bulb sizes on physiological losses of Agrifound light red onion bulbs (*Allium cepa *L.).* - Agric. Sci. Technol., 11(1): 90-97.

ADEYEMO A.E., OMOBA O.S., OLAGUNJU A.I., JOSIAH S.S., 2023 - *Assessment of nutritional values, phytochemical content, and antioxidant properties of shallot (*Allium ascalonicum *L.) leaf and bulb.* - Measurement: Food, 10: 100091.

ANSAR M., BAHRUDDIN, MAEMUNAH, PAIMAN, 2022 - *Effect of harvest age and storage duration on viability and vigor of shallot (*Allium cepa *L.) tubers.* - Res. Crop, 23(4): 815-822.

ARIF A.B., SASIMATALOKA K.S., WIDAYANTI S.M., YULIANI S., 2022 - *Effect of pelleting on germination and vegetative growth of true seed of shallot (*Allium cepa *var ascalonicum* L.). - Songklanakarin J. Sci. Technology, 44(3): 811-816.

AYU I.W., SISWANTO H.T., LESTARI N.D., 2023 - *Sosialisasi pasca panen bawang merah pada petani dataran tinggi Kabupaten Sumbawa.* - J. Pengembangan Masyarakat Lokal, 6(1): 117-124.

BENKEBLIA N., ONODERA S., SHIOMI N., 2005 - *Variation in 1-fructo-exohydrolase (1-FEH) and 1-kestose-hydrolysing (1-KH) activities and fructo-oligosaccharide (FOS) status in onion bulbs. Influence of temperature and storage time*. - J. Sci. Food Agric., 85(2): 227-234.

CENTRAL BUREAU OF STATISTICS OF INDONESIA, 2024 - *Produksi tanaman sayuran,* 2021-2023. - https://www.bps.go.id/id/statistics-table/2/NjEjMg==/produksi-tanaman-sayuran.html.

CHOPE G.A., COOLS K., HAMMOND J.P., THOMPSON A.J., TERRY L.A., 2012 a - *Physiological, biochemical and transcriptional analysis of onion bulbs during storage*. - Annals Bot., 109(4): 819-831.

CHOPE G.A., COOLS K., TERRY L.A., HAMMOND J.P., THOMPSON A.J., 2012 b - *Association of gene expression data with dormancy and sprout suppression in onion bulbs using a newly developed onion microarray*. - Acta Horticulturae, 969: 169-174.

CHOPE G.A., TERRY L.A., 2008 - *The role of abscisic acid and ethylene in onion bulb dormancy and sprout suppression*. - Stewart Postharvest Review, 4(2): 5.

CHOPE G.A., TERRY L.A., WHITE P.J., 2006 - *Effect of controlled atmosphere storage on abscisic acid concentration and other biochemical attributes of onion bulbs*. - Postharvest Biol. Technol., 39(3): 233-242.

CHOPE G.A., TERRY L.A., WHITE P.J., 2007 a - *Preharvest application of exogenous abscisic acid (ABA) or an ABA analogue does not affect endogenous ABA concentration of onion bulbs*. - Plant Growth Regul., 52(2): 117-129.

CHOPE G.A., TERRY L.A., WHITE P.J., 2007 b - *The effect of the transition between controlled atmosphere and regular atmosphere storage on bulbs of onion cultivars SS1, Carlos and Renate*. - Postharvest Biol. Technol., 44(3): 228-239.

DUBROVSKY J.G., SAUER M., NAPSUCIALLY-MENDIVIL S., IVANCHENKO M.G., FRIML J., SHISHKOVA S., CELENZA J., BENKOVÁ E., 2008 - *Auxin acts as a local morphogenetic trigger to specify lateral root founder cells.* - Proc. Nat. Acad. Sci. United States Amer. (PNAS), 105(25): 8790-8794.

KIMMELSHUE C.L., GOGGI A.S., MOORE K.J., 2022 - *Single-plant grain yield in corn (*Zea mays *L.) based on emergence date, seed size, sowing depth, and plant to plant distance.* - Crops, 2(1): 62-86.

KUSMALI M., AHMAD U., DARMAWATI E., 2020 - *The effect of curing and leaves cutting in longterm storage of* *shallot.* - IOP Conf. Ser.: Earth Environ. Sci., 542(1): 012009.

LESKOVAR D.I., OTHMAN Y.A., 2021 - *Direct seeding and transplanting influence root dynamics, morpho-physiology, yield, and head quality of globe artichoke*. - Plants, 10(5).

LESTARI R.H.S., SULISTYANINGSIH E., PURWANTORO A., 2018 - *The effect of drying and storage on the quality of shallot (*Allium cepa *L. Aggregatum group) bulbs.* - Ilmu Pertan. (Agric. Sci.), 3(3): 117-126.

LIMAN U.S., 2024 - BPS *sebut bawang merah jadi komoditas pangan dengan inflasi tertinggi*. - ANTARA News, 2 May. - https://www.antaranews.com/berita/4085037/bps-sebut-bawang-merah-jadi-komoditas-pangan-dengan-inflasi-tertinggi

MAEMUNAH, WARDIYATI T., GURITNO B., SUGIARTO A.N., 2015 - *The influence of storage area, storage method and seed quality character on the quality of shallot seed*. - Int. J. Adv. Res. Biol. Sci., 2(1): 158-164.

MCDONALD G.K., MINKEY D., DESBIOLLES J., CLARKE G., ALLEN R., NOACK S., SCHMITT S., AMOUGIS A., 2024 - *Responses to precision planting in canola and grain legume crops*. - Field Crops Res., 315: 109451.

NURFAIDA N., SYAM'UN E., ULFA F., MANTJA K., FARIED M., 2024 - *Breaking dormancy of shallot (*Allium ascalonicum *L.) bulb using hydrogen peroxide.* - J. Tek. Pertan. Lampung, 13(1): 205-212.

PASIGAI M.A., TAHA A.R., NASIR B., LASMINI S.A., MAEMUNAH, BAHRUDIN, 2016 - *Teknologi budidaya bawang merah varietas Lembah Palu*. - Penerbit Untad Press, Palu, Republic of Indonesia, pp. 190.

PUSAT DATA DAN SISTEM INFORMASI PERTANIAN, 2024 - *Analisis kinerja perdagangan komoditas bawang merah*). - Kementerian Pertanian, Jakarta, Vol. 14, No. 1C - https://satudata.pertanian.go.id/ assets/docs/publikasi/1C_Analisis_Kinerja_Bawang_Merah_2024_-_publish.pdf

SARJANI A.S., PALUPI E.R., SUHARTANTO M.R., PURWANTO Y.A., 2018 - *Pengaruh suhu ruang simpan dan perlakuan pasca penyimpanan terhadap mutu dan produktivitas umbi benih bawang merah (*Allium cepa *L. group Aggregatum).* - J. Hortik. Indones., 9(2): 111–121.

SOHANY M., SARKER M.K.U., MOHOMUD M.S., 2016 - *Physiological changes in red onion bulbs at different storage temperature.* - World J. Eng. Technol., 4: 261-266.

SYAM'UN E., YASSI A., JAYADI M., SJAM S., ULFA F., ZAINAL 2017 - *Meningkatkan produktivitas bawang merah melalui penggunaan biji sebagai bibit.* - J. Din. Pengabdian, 2(2): 188-193.

TARIGAN R., MANIK F., BARUS S., 2019 - *The effect of shallot bulbs storage duration and paclobutrazol treatments to disease attack on shallot plant in Karo highlands.* - JERAMI, Indonesian J. Crop Sci., 1(2): 8-15.

YANG C.-Q., LI Q.-H., JIANG X.-Q., FAN Y.-W., GAO J.-P., ZHANG C.-Q., 2015 a - *Dynamic changes in α- and β-amylase activities and gene expression in bulbs of the oriental hybrid lily 'Siberia' during dormancy releas*e. - J. Hort. Sci. Biotechol, 90(6): 753-759.

YANG Y., ZHU Z.-B., GUO Q.-S., MIAO Y.-Y., MA H.-L., YANG X.-H., 2015 b - *Effects of low temperature on dormancy breaking and growth after planting in bulbs of Tulipa edulis.* - J. Chinese Materia Medica, 40(1): 48-52.