

# Incidence of Virus Infection and Weather Conditions in Shallot Center Production in Brebes, Central Java after Outbreak of Sudden Death Disease

## Insidensi Infeksi Virus dan Kondisi Cuaca di Sentra Produksi Bawang Merah di Brebes Jawa Tengah setelah Ledakan Penyakit Mati Mendadak

I Gusti Ayu Widyastiti, Widodo, Sri Hendrastuti Hidayat\*

Department of Plant Protection, Faculty of Agriculture, IPB University  
Kamper Street, IPB Dramaga Campus, Bogor 16680

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### \*Corresponding author:

Sri Hendrastuti Hidayat  
[srihendrastuti@apps.ipb.ac.id](mailto:srihendrastuti@apps.ipb.ac.id)

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### ABSTRACT

Pests and diseases are significant constraints to shallot cultivation in Indonesia. In 2023, sudden death disease, a new disease of shallots locally called “janda pirang” by farmers, was reported. This disease spreads rapidly and widely, especially in shallot production centers in Java Island. This study aimed to analyze the role of viral infection and weather factors in the incidence of sudden death disease through field observations in different seasons following the report of this disease. Field observations were conducted during the rainy and dry seasons in 2025 in Brebes Regency. Molecular virus detection was performed using one-step reverse transcription polymerase chain reaction (RT-PCR) with specific primers for the main shallot viruses. Two viruses were detected, i.e. Onion yellow dwarf virus (OYDV) and Shallot latent virus (SLV); while the other viruses, i.e. Garlic common latent virus (GCLV), Leek yellow stripe virus (LYSV), and Iris yellow spot virus (IYSV) were not detected. Similarly, no population of the thrips vector (*Thrips tabaci*) was found. The incidence of OYDV in the rainy season ranged from 75% to 100% and in the dry season 50% to 100%, while SLV was detected 100% in both seasons, indicating that seasonal differences do not significantly influence its presence due to its bulb-borne nature. Evaluation of weather conditions, in particular temperature and rainfall, indicate that high temperatures and low rainfall may affect the incidence of sudden death disease.

**Keywords:** Iris yellow spot virus, janda pirang, molecular detection, rainfall, thrips

### ABSTRAK

Hama dan penyakit merupakan kendala penting dalam budi daya bawang merah di Indonesia. Pada tahun 2023 dilaporkan terjadinya penyakit mati mendadak yang merupakan penyakit baru pada bawang merah di Indonesia. Penyakit ini secara lokal dikenal dengan istilah “janda pirang” oleh petani. Penyakit tersebut menyebabkan kematian bawang merah dalam skala luas dan dalam periode yang singkat di sentra produksi bawang merah di Pulau Jawa. Penelitian ini bertujuan menganalisis peran infeksi virus dan faktor cuaca terhadap insidensi penyakit mati mendadak melalui pendekatan pengamatan lapangan pada musim yang berbeda pasca insidensi mati mendadak bawang merah. Pengamatan lapangan dilakukan pada musim hujan dan kemarau selama tahun 2025 di Kabupaten Brebes. Deteksi virus secara molekuler dilakukan menggunakan metode *one-step reverse transcription polymerase chain reaction* (RT-PCR) dengan primer spesifik terhadap virus utama bawang merah. Terdapat dua virus yang terdeteksi, yaitu Onion yellow dwarf virus (OYDV) dan Shallot latent virus (SLV), sedangkan Garlic common latent virus (GCLV), Leek yellow stripe virus (LYSV), dan Iris yellow spot virus (IYSV) tidak terdeteksi. Demikian pula, populasi vektor trips (*Thrips tabaci*) tidak ditemukan. Insidensi OYDV pada musim hujan mencapai 75%–100% dan pada musim kemarau 50%–100%, sedangkan SLV terdeteksi 100% pada kedua musim. Hal ini mengindikasikan bahwa perbedaan musim tidak berpengaruh signifikan terhadap keberadaan OYDV dan SLV karena sifatnya yang terbawa umbi. Analisis cuaca terutama faktor suhu dan curah hujan mengindikasikan pengaruh suhu tinggi dan curah hujan rendah terhadap insidensi penyakit mati mendadak.

**Kata kunci:** curah hujan, deteksi molekuler, janda pirang, Iris yellow spot virus, trips

## INTRODUCTION

Shallots (*Allium cepa* var. *aggregatum*) represent the most extensively produced horticultural commodity in Indonesia. In 2024, shallot production reached 2 085 721 tons, accounting for 14.15% of the total national vegetable production, with a harvested area of 188 796 ha. In September 2023, sudden death disease, known by local farmers as “penyakit janda pirang”, were reported from several shallot production areas in Java. This condition is characterized by dry and necrotic leaves, resulting in a straw-bleaching appearance. The sudden death outbreak has been documented across several major shallot producing regions, including Cirebon, Brebes, Kulonprogo, and Nganjuk. Consequently, significant reductions in harvested areas were reported in Central Java (6798 ha), West Java (1380 ha), and East Java (591 ha) (Ditjen Horti 2025). This mass mortality occurred rapidly on a large scale and represents a novel symptomology not previously reported in previous years.

The occurrence of sudden death coincided with a population outbreak of thrips (Ananda *et al.* 2024). The presence of thrips during this period requires further analysis regarding their role in the manifestation of sudden death symptoms. Thrips cause direct damage to plants through their feeding behavior, which disrupts cell walls and induces silvery discoloration in plant tissues (Rodriguez and Coy-Barrera 2023). Additionally, thrips pose an indirect threat as viral vectors. The onion thrips, *Thrips tabaci*, is a known vector for viruses within the genus *Orthotospovirus* (Garcia-Rodriguez *et al.* 2014). Large vector populations raise concerns regarding the potential transmission of viruses such as Iris yellow spot virus (IYSV) (Komondy *et al.* 2024). Therefore, viruses associated with shallots require further investigation, particularly in production centers where sudden death has occurred. The viruses commonly found in Indonesian shallot production areas are bulb-borne, including Onion yellow dwarf virus (OYDV), Shallot yellow stunt virus (SYSV), Leek yellow stripe virus (LYSV), Shallot latent virus (SLV), and Garlic common latent virus (GCLV), recently Garlic virus C (GarV-C) and Iris yellow spot virus (IYSV) was also identified from shallot (Harti *et al.* 2020; Yuliandini *et al.* 2026). However, there is a lack of research examining the association of shallot viruses with the incidence of shallot sudden death.

Climate factors represent another essential aspect to be analyzed in relation to the shallot sudden death phenomenon. Climatic conditions drive the dynamic between viruses, vectors, and host plants, particularly during unfavorable seasonal periods characterized by rising temperatures, fluctuating water availability, frequency of extreme weather, and elevated CO<sub>2</sub>

concentrations (Trebecki 2020). As poikilothermic organisms, insects are highly sensitive to temperature, which significantly affects their metabolism, growth, and development. Increased temperatures can shorten life cycles and lead to higher insect populations (Shrestha 2019). In *T. tabaci*, rising temperatures influence the sex ratio to produce more female offspring, accelerate the pre-oviposition period, and increase fecundity (Woldemelak *et al.* 2021). Furthermore, high temperatures accompanied by drought stress weaken plant defenses. Drought triggers an increase in leaf nitrogen concentration, which enhances the feeding preference of sap-feeding insects (Acosta *et al.* 2022; Gido and Lehoczky 2024). In contrast, drought often has an antagonistic relationship with viruses, where such conditions may reduce viral transmission, delay symptom expression, and decrease both virulence and severity (Berges *et al.* 2018; Sadras *et al.* 2023; Jimenez *et al.* 2024). The objectives of this study were to analyze the contribution of viral infection and seasonal weather factors to the incidence of sudden death disease through field observations conducted across different seasons following the initial report.

## MATERIALS AND METHODS

### Field Observation and Samples Collection

Field observations were conducted in shallot fields located in Wanasari District, Brebes Regency, Central Java Province. This location was selected as it was the primary location of the shallot sudden death outbreak in 2023. Observations were carried out during the rainy season (February to April 2025) and the dry season (May to July 2025). Disease observations were performed across four shallot fields from 20 days after planting until harvest, with an observation interval of 10 days. Within each field, five observation subplots were established following a diagonal sampling method. Ten sample plants were randomly selected from each subplot using a zigzag pattern, resulting in a total of 50 sample plants per field. The variables observed for each sample plant included symptoms of viral infection and thrips population density. For laboratory detection and identification purposes, leaf samples from the 50 plants in each field were collected and pooled into composite samples. These leaf samples were then placed in plastic bags containing silica gel, labelled, and stored for further analysis.

### Climate Data Collection

Climate data for the 2021–2025 period were obtained from the BPS-Statistics Indonesia (BPS) and the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) for the shallot production center in Brebes, Central Java, and Nganjuk, East Java.

These two regencies were identified as the locations of the sudden death outbreak in 2023. The collected climatic parameters included rainfall, air temperature, and relative humidity. The influence of these climatic factors on the incidence of sudden death disease was analyzed using comparative descriptive analysis

**Virus Detection using Reverse Transcription Polymerase Chain Reaction (RT-PCR)**

Leaf samples collected from the field were weighed at 0.01 g in dry condition. Total RNA extraction from the shallot leaf samples was performed using an GeneJET RNA Purification Kit (Thermo-Fisher Scientific, Waltham, US). The extracted RNA served as a template for the amplification of targeted viruses. Amplification of SLV, LYSV, OYDV, and GCLV was conducted using specific primers, while IYSV was detected using degenerate primers (Table 1). These five viral targets were selected due to their high prevalence and known economic significance in shallot cultivation within the region. However, mixed viral infections are common under field conditions. This targeted approach may not capture the complete viral diversity, and the occurrence of other undetected viruses cannot be entirely excluded. The one-Step RT-PCR premix composition consisted of 12.5 µL DreamTaq Green Master Mix (Thermo Fisher Scientific, US), 1 µL 0.1 M DTT (Smobio, Taiwan), 0.5 µL RNase inhibitor (Thermo Fisher Scientific, US), 0.25 µL RT Enzyme (200 U µL<sup>-1</sup>) (Smobio, Taiwan), 2 µL RNA template, 2 µL of each 10 µM forward and reverse primers, and 4.75 µL nuclease-free water.

Virus amplification was performed using the GeneAmp® PCR System 9700 (Applied Biosystems, US). The amplification program for SLV, LYSV, OYDV, and GCLV included a cDNA synthesis stage at 45 °C for 60 minutes, followed by pre-denaturation at 94 °C for 1 minute. This was followed by 35 cycles consisting of denaturation at 94 °C for 30 seconds, annealing at 50 °C for 30 seconds, extension at 72 °C for 1 minute, and a final elongation at 72 °C for

10 minutes (Haque and Hattori 2017). IYSV detection followed the method by Nurulita *et al.* (2024) with modifications in the number of cycles and annealing period. The one-step RT-PCR for IYSV involved cDNA synthesis at 50 °C for 20 minutes, followed by pre-denaturation at 95 °C for 1 minute, and 40 cycles of denaturation at 95 °C for 10 seconds, annealing at 52 °C for 20 seconds, extension at 72 °C for 30 seconds, and a final elongation at 72 °C for 2 minutes.

Visualisation of the amplified DNA was performed via gel electrophoresis using 1% agarose gel stained with 1% FluoroVue™ nucleic acid gel stain in 0.5× tris-borate-EDTA (TBE) buffer for 30 minutes at 100 V. The electrophoresis results were visualized using a UV transilluminator. The resulting DNA fragments were further analyzed using the Sanger sequencing method. The obtained sequence data were then compared with the NCBI GenBank database using the Basic Local Alignment Search Tool (BLAST) feature to determine viral identity. Subsequently, the nucleotide sequences were analyzed for homology and phylogeny using BioEdit version 7.7.1, MEGA 11, and SDTv1.2 software.

**RESULTS**

**Viruses Identified Across Two Planting Seasons**

The RT-PCR method detected two species of viruses, SLV and OYDV, from shallot samples in Brebes (Table 2). Other target viruses (IYSV, LYSV, and GCLV) were not detected in any of the shallot samples from either planting season. The primary shallot viruses, including SLV, OYDV, LYSV, and GCLV, are bulb-borne, whereas IYSV is a vector-borne virus transmitted by *T. tabaci* (Garcia-Rodriguez *et al.* 2014; Harti *et al.* 2020). The incidence of SLV reached 100% in each planting season, while OYDV incidence varied, ranging from 75% to 100% in the rainy season and 50% to 100% in the dry season (Table 2). Furthermore, OYDV detection results showed a decreased incidence in older plants or those that had

Table 1 Primers used for the detection of shallot viruses

| Target virus | Primer code | Primer sequences (5'- 3')      | Target size (bp) | Reference                     |
|--------------|-------------|--------------------------------|------------------|-------------------------------|
| SLV          | GS-RT1      | TATGCTCGAGCTCGTAGAGC           | 170              | Haque and Hattori (2017)      |
|              | GS-RT2      | GGGTTTCACATTGTTACACC           |                  |                               |
| LYSV         | P-RT3       | AAGAGTCAACACTTGGTTTG           | 191              | Haque and Hattori (2017)      |
|              | P-RT4       | GGTCTCAATCCTAGCTAGTC           |                  |                               |
| OYDV         | OG-RT1      | GAAGCGCACATGCAAATGAAG          | 290              | Sumi <i>et al.</i> (2001)     |
|              | OG-RT2      | CGCCACAAC TAGTGGTACAC          |                  |                               |
| GCLV         | GCLV-F      | ATGTCAGTGAGTGAAACAGAGG         | 960              | Parrano <i>et al.</i> (2012)  |
|              | GCLV-R      | CTAGTCTGCATTGTTGGATCC          |                  |                               |
| IYSV         | TospoRp-F1  | ATGGGIATITTTYGAYTTYATGIGRYATGC | 307              | Nurulita <i>et al.</i> (2024) |
|              | TospoRp-R1  | GGCATCATRTAIATIGCIARRTAIACATT  |                  |                               |

passed the generative phase. As described by Conci *et al.* (2009), OYDV concentrations are typically higher in younger leaves compared to older leaves.

Most leaf samples from the field were asymptomatic despite the positive detection of OYDV and SLV. Several types of symptoms observed in the field included leaf flattening and wrinkling, stunting, and yellowing (Figure 1). Marais *et al.* (2019) explained that SLV infection is often asymptomatic in *Allium* plants but can cause severe damage when involved in co-infections with members of the *Potyvirus* genus. The detection of SLV and OYDV in Brebes is associated with their bulb-borne nature (Harti *et al.* 2020). This suggests that the seed bulbs used by farmers in Brebes were already infested with the viruses.

The identities of OYDV and SLV from Brebes were further confirmed through sequence analysis, and the virus sequences of the Brebes isolates have been registered in GenBank under accession numbers LC918503.1 (OYDV) and LC918505.1 (SLV). BLAST results indicated that the OYDV-LC918503.1 isolate from Brebes shares high homology (97.80%) with an isolate from Japan (AB000843.1). Meanwhile, the SLV-LC918505.1 isolate from Brebes showed high homology (95.86%) with an Indonesian SLV isolate (OR180056.1).

Comparative analysis using sequence demarcation tools (SDT) of the obtained OYDV isolates showed high pairwise identity, ranging from 90.4% to 96.5%. The Indonesian OYDV isolate LC918503.1 demonstrated the highest sequence similarity (96.5%) with the Japanese isolate (AB000843.1), while the

lowest similarity (90.4%) was with a Vietnamese isolate (DQ925454). Overall, OYDV nucleotide similarity remains high despite variations in host plants, including shallots, garlic, and leeks (Figure 2). The Indonesian SLV isolate (LC918505.1) obtained in this study exhibited moderate variability, with pairwise sequence identity ranging from 82.24% to 95.86%. This isolate (LC918505.1) showed high similarity with other Indonesian SLV isolates but demonstrated low pairwise identity values compared to isolates from other countries and different hosts (Figure 3). The Tomato spotted wilt virus (TSWV) isolate was included as an outgroup for the SDT analysis to enable interspecific comparison, yielding the lowest pairwise identity values among all analysed sequences.

Thrips populations were not found in any of the fields during the two observation seasons. Accordingly, the diamond-shaped, straw-colored symptoms of IYSV were also absent. IYSV is not a bulb-borne virus and naturally requires the vector *T. tabaci* for transmission (He *et al.* 2019). Farmers in Brebes Regency apply irrigation every morning by pouring high volumes of water directly onto the shallot clusters. This irrigation technique likely influences thrips populations, as thrips are easily washed off from plants by irrigation or rainfall (Ibrahim and Adesiyun 2010).

**Weather Conditions in Brebes During and After the Sudden Death Outbreak**

The occurrence of shallot sudden death was not detected during the 2025 field observations in Brebes. In 2023, this disease emerged during the dry season,

Table 2 Incidence (%) of shallot viruses during two planting seasons in Brebes in 2025 based on RT-PCR detection

| Plant age (days) | Rainy season |     |      |      |      | Dry Season |     |      |      |      |
|------------------|--------------|-----|------|------|------|------------|-----|------|------|------|
|                  | OYDV         | SLV | GCLV | LYSV | IYSV | OYDV       | SLV | GCLV | LYSV | IYSV |
| 20               | 100          | 100 | 0    | 0    | 0    | 100        | 100 | 0    | 0    | 0    |
| 30               | 100          | 100 | 0    | 0    | 0    | 100        | 100 | 0    | 0    | 0    |
| 40               | 75           | 100 | 0    | 0    | 0    | 75         | 100 | 0    | 0    | 0    |
| 50               | 75           | 100 | 0    | 0    | 0    | 50         | 100 | 0    | 0    | 0    |

\*Detection of each virus was performed using composite samples for each location.

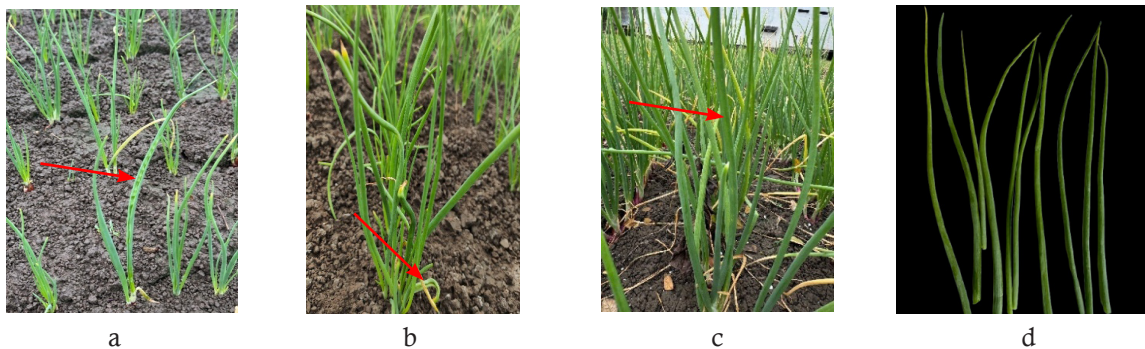


Figure 1 Symptoms found on shallots in Brebes. a, wrinkled leaves; b, flattened leaves and stunted plants; c, yellowing; and d, asymptomatic leaves.

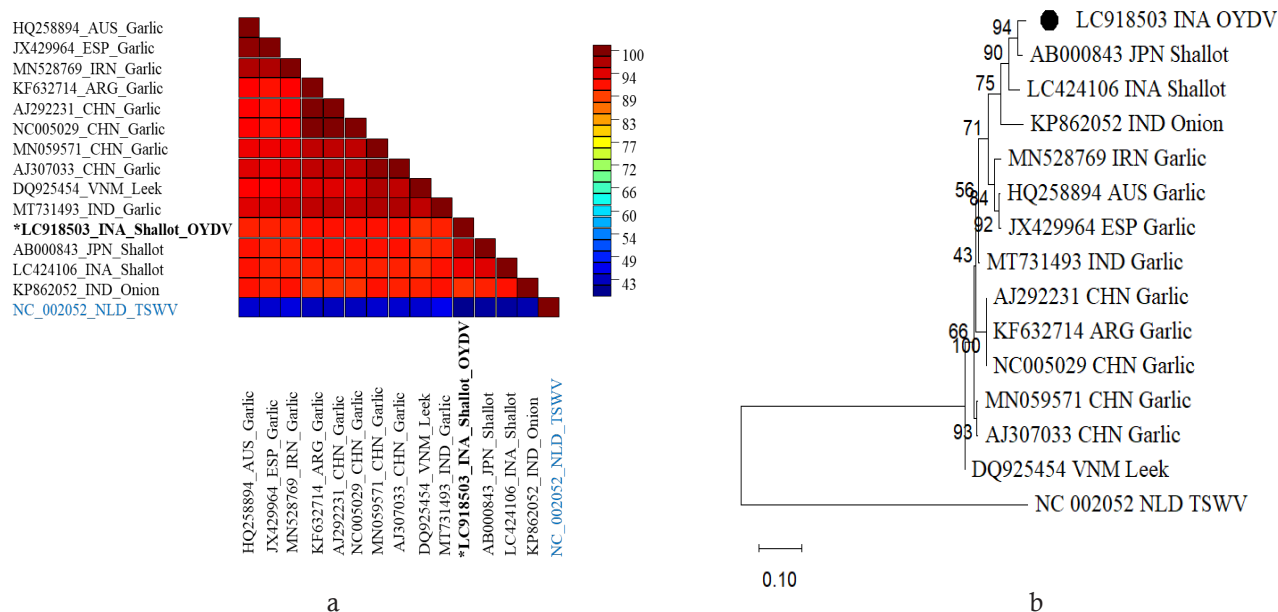


Figure 2 a, Sequence demarcation tool (SDT) matrix and b, phylogenetic tree of Onion yellow dwarf virus (OYDV). The OYDV isolate from this study is marked in black dot. The Tomato spotted wilt virus (TSWV) isolate, indicated in blue, was used as the outgroup.

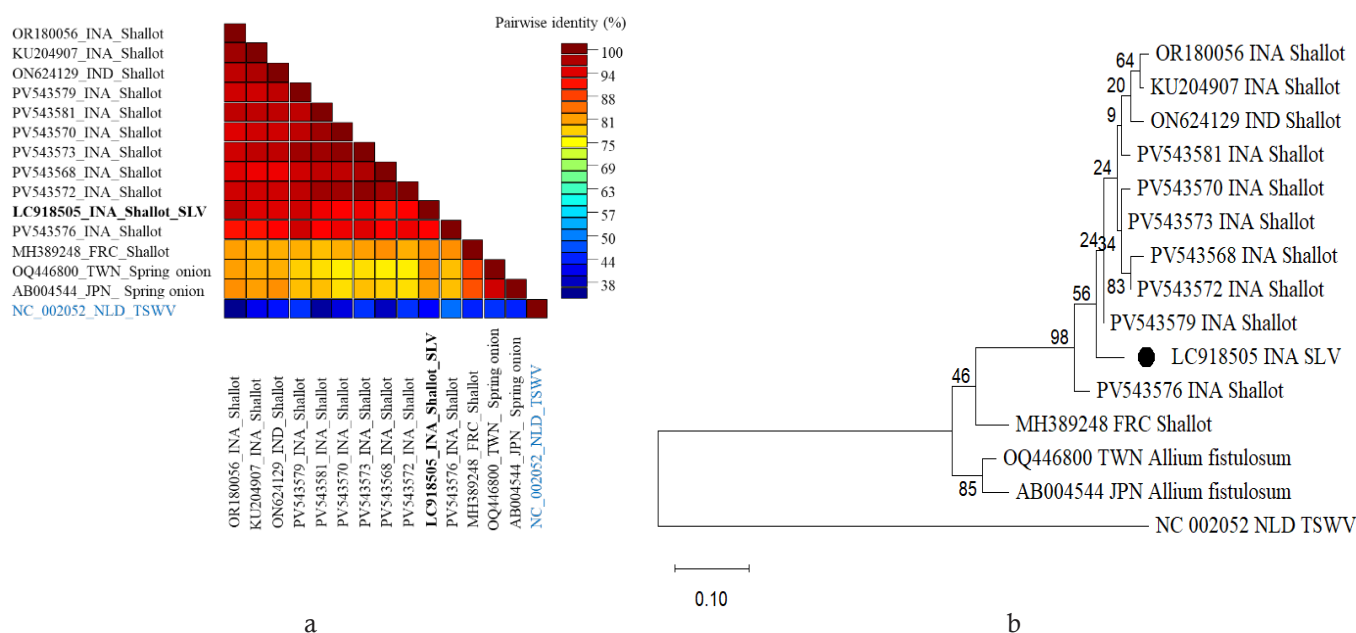


Figure 3 a, Sequence demarcation tool (SDT) matrix and b, phylogenetic tree of Shallot latent virus (SLV). The SLV isolate from this study is marked in black dot. The Tomato spotted wilt virus (TSWV) isolate, indicated in blue, was used as the outgroup.

approximately from September to October. Weather data indicate that the 2023 dry season experienced an increase in average temperature and the lowest rainfall compared to 2021 and 2022. During August and September 2023, Brebes experienced two consecutive months without rainfall, while maximum temperatures reached 33.5 °C (Figure 4). The average relative humidity (RH) in September 2023 reached its lowest point in the last five years at 69%, whereas the RH during the peak of the dry season in other years ranged

between 74%–79% (BPS 2025a). Based on interviews with local farmers in Brebes, shallot sudden death was most severe in 2023, subsequently decreased in intensity in 2024, and was not found in 2025. Overall, the 2024 dry season from May to October had higher rainfall and humidity compared to 2023 (BMKG 2025).

Similar conditions were observed in Nganjuk Regency, where the sudden death outbreak in 2023 occurred on a large scale but was absent in 2025. In 2023, Nganjuk Regency experienced extreme

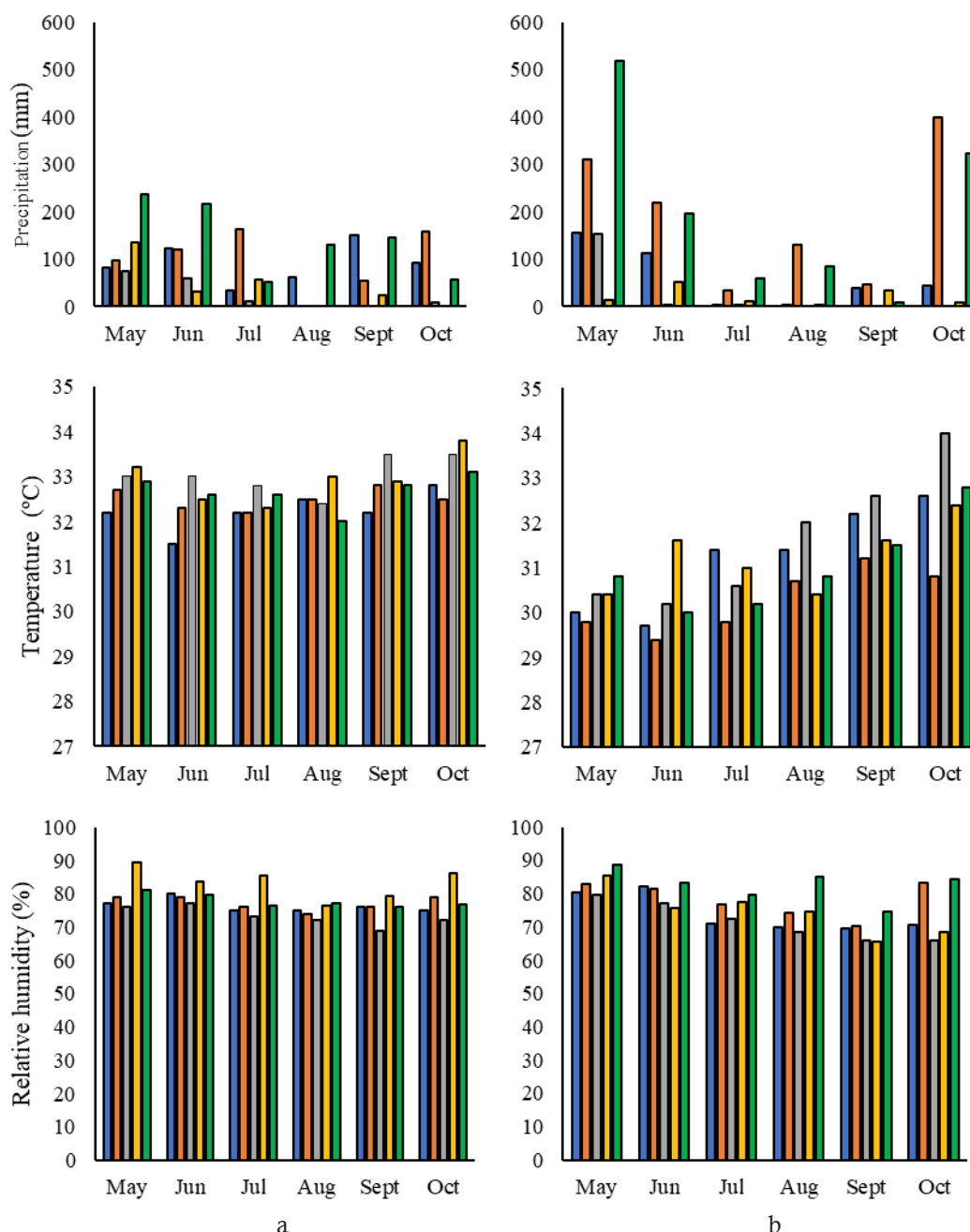


Figure 4 Weather data (precipitation, temperature, and relative humidity) in Brebes and Nganjuk Regencies for the 2021–2025 period (Source: BPS 2025a; BPS 2025b; BMKG 2025). a, Brebes; b, Nganjuk; ■, 2021; ■, 2022; ■, 2023; ■, 2024; and ■, 2025.

conditions with no rainfall for three consecutive months (August, September, and October), recorded the highest average temperatures, and the lowest RH within the 2021–2025 period. The weather conditions during that period differed significantly from 2025, which experienced above-normal rainfall anomalies during the dry season, a phenomenon referred to as a “wet dry season” (BMKG 2025).

The peak of the 2025 dry season in Brebes was estimated to occur between July and August; however, rainfall during this period remained relatively high, ranging from 52.7 to 130.9 mm, with average maximum temperatures of 32–32.9 °C and relative humidity of

76%–77%. Meanwhile, in Nganjuk Regency, the 2025 dry season peak recorded rainfall of 59–84.9 mm, with average maximum temperatures of 30.2–30.8 °C and relative humidity of 79%–85% (BMKG 2025; BPS 2025b). In 2023, Indonesia experienced an El Niño event that persisted until the end of the year, with maximum temperatures reaching 37 °C (BMKG 2023). Heat and water deficit caused extreme stress in shallot plants. In contrast, 2025 was characterized by a “wet dry season,” providing adequate water availability and lower temperatures.

Comparative descriptive analysis of the weather data in Brebes and Nganjuk highlighted a stark

contrast in climatic trends between 2023 and 2025. The data revealed that the outbreak of shallot sudden death in 2023 strongly coincided with a marked increase in average temperatures and a prolonged absence of rainfall (0 mm) during the critical months of August and September. Conversely, in 2025, when no disease occurred, the regions experienced lower average temperatures and substantially higher rainfall, suggesting that the synergistic stress of extreme heat and drought in 2023 served as the primary driver for the disease outbreak. These results indicate that while higher temperatures strongly drive the outbreak of shallot sudden death, increased rainfall acts as a limiting factor that suppresses the occurrence of the disease.

## DISCUSSION

Shallot sudden death is a new disease in Indonesia, first reported in 2023 in Nganjuk, East Java, and other production regions, including Brebes, Central Java. Geographically, reports of this disease remain limited to shallot cultivation areas in Java Island, particularly in low altitude regions with high monoculture planting intensity. Both Brebes and Nganjuk are located in lowlands and share similar cultivation characteristics, primarily practicing monoculture with crop rotations that typically involve rice during the rainy season or other horticultural crops. The shallot varieties grown are dominated by 'Tajuk' in Nganjuk and 'Bima Brebes' in Brebes, which are independently propagated by farmers by setting aside a portion of their harvest. Such self-propagation without adequate seed treatment has the potential to accumulate bulb-borne pathogens, such as OYDV and SLV, which are bulb-borne (Harti *et al.* 2020), and co-infections of these two viruses are commonly found in Indonesia (Nurenik *et al.* 2021). In this study, co-infection of shallot plants by OYDV and SLV in Brebes reached 87.5% of the total sampled plants during the rainy season and 81.5% during the dry season. The relatively similar incidence across seasons suggests that seasonal variation may play a minor role in virus occurrences, potentially reflecting the bulb-borne nature of these viruses, which allows persistence independent of environmental fluctuation.

Based on observations in 2025, shallot sudden death was not detected in the field, reinforcing the hypothesis that the emergence of this disease is driven by climatic variables. In 2023, Indonesia experienced an El Niño phenomenon that triggered elevated temperatures. This condition led to an increase in maximum temperatures, coupled with the lowest relative humidity (RH) recorded in the last five years (69%), which stands in stark contrast to the "wet dry season" conditions of 2025. Comparative descriptive analysis

demonstrates the influence of these two climatic variables on sudden death, indicating that the disease is not caused by a single pathogen but is rather the result of complex interactions triggered by high temperatures and water deficits.

High temperatures and low water availability cause extreme stress in plants, which is further exacerbated by field conditions. The use of high raised beds (80–120 cm), originally intended for drainage and irrigation efficiency, became problem during extreme drought. Shallot cultivation generally employs high raised beds and flooded furrows to facilitate maintenance and watering. However, when water levels recede, plants become more susceptible to drought. High raised beds have a larger surface area in contact with the air, thereby increasing evaporation rates. During the dry season, water levels shrink to the bottom of the furrows, causing the relatively shallow root zones of shallots to rapidly lose moisture.

Physiologically, plants from the genus *Allium* exhibit high sensitivity to water stress, which leads to significant reductions in growth parameters, decreased chlorophyll content, and cellular damage (Singh *et al.* 2024). The combination of heat and drought triggers the formation of reactive oxygen species (ROS) and directly impacts bulb weight. Under extreme conditions, drought can induce plant mortality due to high tension, which reduces carbon dioxide uptake and photosynthesis (Johnson *et al.* 2022). At the critical point, the loss of turgor pressure and metabolic failure caused by extreme heat manifest as the sudden death symptoms observed in 2023.

In 2025, despite the high incidence of bulb-borne viruses such as SLV and OYDV, no occurrences of sudden death were detected. This demonstrates that while these shallot viruses persist across generations, they are not the primary cause of sudden death. Results showing that shallot viruses are not solely responsible reinforce the hypothesis that high temperature stress and extreme drought are the primary drivers of the disease, indirectly influencing biotic factors within the cultivation environment. Under the "wet dry season" conditions of 2025, adequate water availability and lower temperatures maintained plant homeostasis; consequently, despite being virus-infected, the plants did not reach a point of physiological collapse.

Abiotic factors, such as temperature and rainfall, also significantly influence insect population dynamics and pathogen emergence. The exceptionally high thrips populations recorded in Brebes in 2023 stand in stark contrast to 2025, where thrips were entirely absent during both planting seasons. Increased temperatures can accelerate the pre-oviposition period of thrips, enhance fecundity, and hasten egg maturation. These factors lead to a faster reproductive cycle and trigger

a rapid increase in thrips populations (Sridhar *et al.* 2025), which likely contributed to the population outbreaks observed in 2023.

In summary, the shallot sudden death disease showed a declining incidence from 2023 to 2024 and was not found in 2025. This provides an important note that future management of sudden death must focus not only on cultivation factors, such as seed health and pest and disease control, but also on climate change mitigation. While crop rotation patterns can help break pathogen cycles, plant vulnerability to extreme temperatures remains a significant risk factor, as statistical modelling indicates that temperature anomalies are strongly associated with disease occurrence. Cultivation adaptation strategies against extreme weather must be further considered to prevent the potential recurrence of this disease during prolonged droughts or future El Niño events.

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