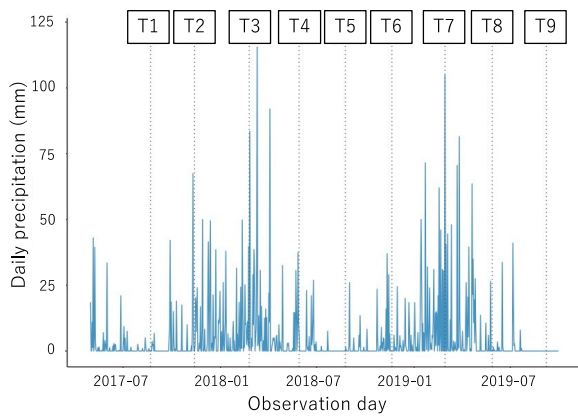


## Waterlogging due to rainfall alters gene expression patterns in the upper stem of oil palm

Palm oil accounts for approximately 36% of global vegetable oil production, making it the most abundant. However, the majority of this production occurs in Southeast Asia, specifically in Indonesia and Malaysia. The geographical concentration of production systems is considered vulnerable to climate change. To reveal the weather factors affecting oil palm (*Elaeis guineensis*), we comprehensively analyzed the gene expression levels of oil palm tissues collected over time (transcriptome analysis). By examining the relationship between meteorological factors and oil palm, we can unravel its physiological responses to environmental conditions. Understanding oil palm's physiological responses to environmental factors can help identify vulnerabilities to climate change and contribute to sustainable oil palm plantation management.

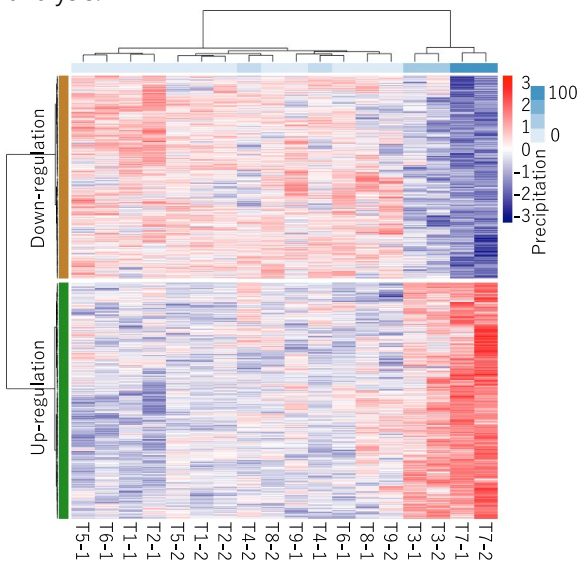
At the research site in Lampung Province, Indonesia, samples were collected from the leaf and stem tissues of oil palm for transcriptome analysis over a time series (Figs. 1 and 2). Sampling was conducted approximately nine times over two years (T1 to T9). Notably, during sampling at T3 and T7, there were rainfall events exceeding 80 mm per day. The gene expression profiles of samples obtained from the oil palm stem tissues at T3 and T7 differed significantly from those at other time points (Fig. 3). However, there was no clear relationship between the gene expression profiles from both tissues and the daily average temperature or cumulative temperature. To investigate the gene expression patterns related to waterlogging, we categorized genes into those associated with waterlogging and those unrelated, based on homology searches with the model plant *Arabidopsis thaliana*. In the trunk tissues, the proportion of genes related to waterlogging showed significant expression variation in both upregulation and downregulation compared to other gene groups. Conversely, such a trend was not observed in leaf tissues (Fig. 4). The homology search results for *A. thaliana* and oil palm revealed substantial differences in gene expression levels related to low oxygen response and oxygen levels. Additionally, changes in gene expression related to ethylene response were evident, indicating stress responses to waterlogging (Fig. 5). These findings suggest that while mature oil palms exhibit resilience to temperature fluctuations, they are sensitive to stress responses in stem tissues under short-duration, heavy rainfall conditions, highlighting their vulnerability to waterlogging.

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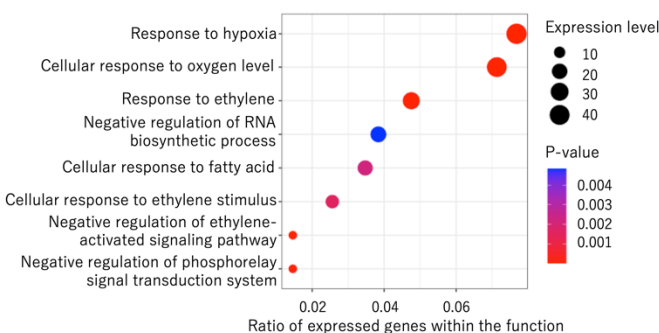
**Fig. 1. Daily precipitation at the study site (Lampung Province, Indonesia) during the observation period**

T1 to T9 indicate sampling dates for transcriptome analysis.

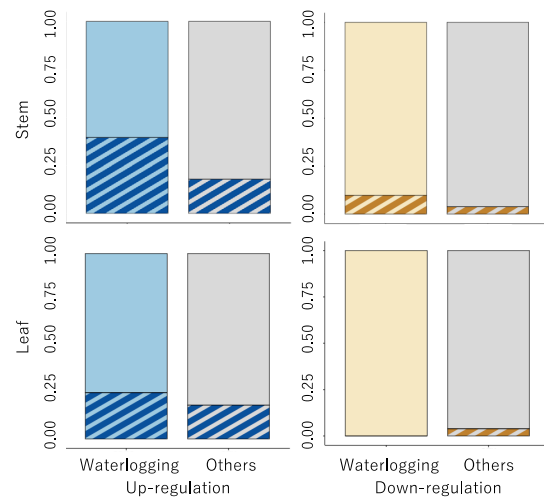


**Fig. 3. Heatmap of the gene expression profile of stem**

By arranging profiles based on daily precipitation, a heatmap reveals significant differences in gene expression profiles between T3, T7, and other samples with high daily precipitation.



**Fig. 2. Studying and sampling of old palm trunk tissue**



**Fig. 4. Proportion of differentially expressed genes in waterlogging-related gene sets and other gene sets during waterlogging**

Distinct patterns of gene expression, especially in stem between waterlogging-related genes and other gene sets, were found when investigating the proportion of differentially expressed genes (diagonal in the bars) during waterlogging (T3 and T7).

**Fig. 5. Functions of genes differentially expressed during waterlogging in stems**

We found that significantly differentially expressed genes are primarily associated with low-oxygen response and oxygen levels. Additionally, changes in gene expression related to ethylene response were also observed.

Reference: Lim et al. (2023) *Frontiers in Plant Science* 14: 1213496. © The Author(s) 2023  
The figures were modified from Lim et al. (2023)