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DREB1 Gene in Regulating Drought Tolerance in Cereal Plants

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Abstract *– This study aims to explain the role of the DREB1 gene in increasing drought tolerance in plants with an emphasis on recent advances in genetic engineering. In this research, the method used is a literature review by collecting library data, reading and taking notes, and critically managing research data related to the DREB1 gene. In this research, data analysis starts by examining the results from studies that are most relevant to the research problem. The results of the literature review obtained indicate that the DREB1 gene is a transcription factor that plays a role in regulating a number of other genes related to drought characteristics. The DREB genes participate in hormone signalling pathways and regulate proteins that interact with downstream genes to improve plant stress tolerance. When there is a drought, seedlings that have the DREB gene inserted have a survival rate of 36%, while plants without the DREB gene all die. These results indicate that the DREB1 gene is a positive regulatory gene for heat tolerance in plants. In this case, the transgenic lines keep their stomata partially closed, which helps maintain a minimum transpiration rate to cool the canopy and reduce the temperature of both the canopy and leaves. We achieve this by coordinating the control of stomata, minimising water loss, and preserving cell turgor, all of which prevent the plant from dying.*

Keywords: *DREB1, cereal plants, drought, transcription factors*

INTRODUCTION

Indonesia is a tropical country with two seasons, namely the dry season and the rainy season. This situation significantly affects Indonesian agriculture, particularly when the dry season lengthens. Both ornamental and agricultural plants will face water shortages, which can lead to drought if the long dry season occurs. This causes many plants to experience a decrease in productivity and even die due to this drought. Cereal crops, one of Indonesia's main commodities, are not immune to the impact of the drought problem. Cereal plants are types of grain that provide carbohydrates for humans.

One example of a cereal crop is rice. Rice is an agricultural commodity that is important for humans, especially for the Indonesian people, who make rice their staple food. Rice is a plant that belongs to the cereal group. Considering that the rice sector is critical for national food security, it is critical to maintain this development. Rice is the most important commodity to meet national food needs because 90% of Indonesian people still consume rice as a source of carbohydrate food. The impact of the decline in rice plant productivity will be greatly felt. Not only rice, but soybeans are also cereal crops. Soybeans are the cheapest and most important protein source commodity in Indonesia. Indonesia has a high dependence on soybean imports; soybean production is 70700,000–800,000 tonnes/year, while the need for soybeans in Indonesia per year reaches 2.2 million (Mustaqal et al., 2020, and Muthurajanan et al., 2021).

We need to increase cereal crop production to combat the growing human population. Cereal plants with drought-tolerant properties could be one answer to this problem. Through genetic engineering, cereal plants with drought-resistant properties can be assembled by inserting genes that have drought-tolerant properties (Ahsan et al., 2022). The main aim of cereal breeding is to develop varieties that have high yield potential as indicated by morphological and agronomic characters. Resistance to pests and diseases, as well as the quantity and quality of seeds, will demonstrate the superior properties of the plant. Breeding efforts are more minimising yield losses in unfavourable conditions, namely drought, and maximising crop yields in favourable conditions (Li et al., 2020).

Researchers have developed genetically engineered plants that overexpress transcription factor genes to increase plant tolerance to stress, as well as genes that respond to abiotic stress, such as high salinity, drought, and cold. This breeding is carried out by inserting the OsDREB gene, which will regenerate drought-tolerant traits in cereal plants and produce plants that are adaptive to drought (Abbas et al., 2024). Apart from cereal plants, the DREB1 gene can also be applied to other plants that have the potential to experience water shortages during the dry season (Li et al., 2021).

The DREB1 gene is a gene from the rice genome that helps control other genes related to drought, meaning if this gene is active in a plant, the plant will be better at handling dry conditions. If a plant expresses a DREB-based gene, it will have characteristics that make it resistant or tolerant to drought. Therefore, this study aims to determine the role of the DREB1 gene in cereal plants (Paul et al., 2022).

MATERIALS AND METHODS

The research is a study literature. This research begins with collecting library data, reading and taking notes, then managing research data objectively, systematically, analytically and critically, especially regarding the DREB1 gene. This literature study research analyzes it in depth to obtain objective results. Furthermore, the data analysis technique in this research uses content analysis techniques. Data analysis begins by analyzing the research results from those that are most relevant to the research problem.

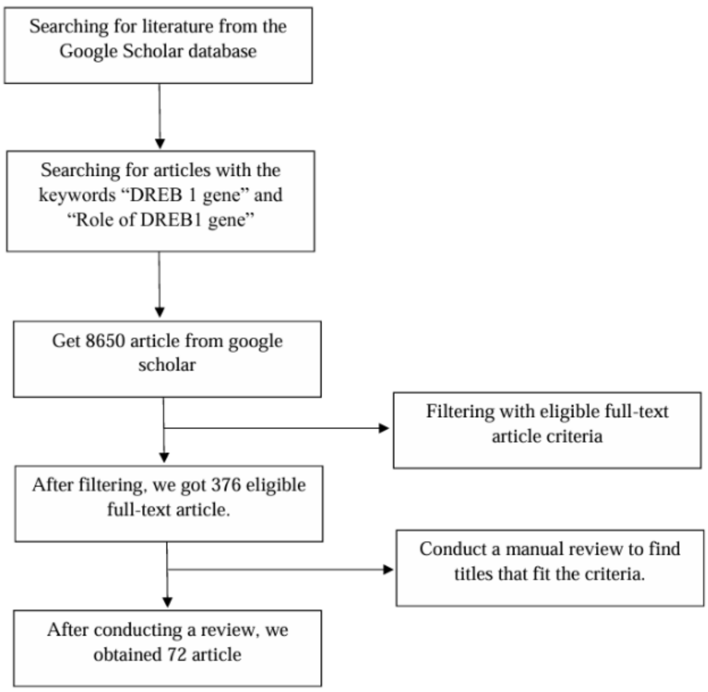

Figure 1. PRISMA Diagram for included studies (Aisyah and Jatmiko, 2024)

RESULT AND DISCUSSION

1. Gen DREB1

Figures 1 showed that the DREB1 gene is a gene related to drought characteristics, namely a DREB (Dehydration Response Element Binding) based gene. The DREB gene transcription factor, referred to as C-repeat binding factor (CBF) and belongs to the ERF (Ets2 Repressor Factor) subfamily and can increase stress tolerance in plants (Kang et al. 2011). These proteins function through interactions with dehydration responsive cis-elements of the promoter regions of several genes that are induced in response to abiotic stress. Due to the central role of DREB/CBF in abiotic stress responses and its ability to regulate a large number of downstream stress-responsive genes, DREB genes have become popularly used to increase abiotic stress tolerance in plants using genetic engineering (Febrianti et al, 2022).

Abiotic stress triggers various biochemical and physiological responses in plants. Plant responses to drought are analyzed through changes in gene expression during drought (Lifang et al, 2023). The analysis results were then classified into two groups, namely the group that directly protects against environmental stress and the group that regulates gene expression and signal transduction during the stress response (Kohan et al. 2012). One type of protein that plays a role in biotic and abiotic stress responses is the ERF protein. DREB is one part of the ERF protein transcription factor through a transduction pathway that does not depend on the abscisic acid (ABA) pathway. Drought is a type of abiotic stress in plants that affects plant function (Wang et al, 2024 and Wani et al, 2025). The ABA pathway plays a role in plant tolerance to drought and most of the genes that can be induced by ABA can also be induced by drought stress (Agarwal et. al, 2006). Drought tolerance is a complex trait that depends on how long and how high the level of stress is given to the plant compared to its survival rate. The survival index is an indicator in identifying drought tolerance traits in genes (Mei et al., 2022 and Wu et al, 2022).

The DREB gene functions in drought regulation by maintaining homeostasis and water balance in rice under conditions of water shortage (Wang et al, 2023). In addition, DREB also plays a role in regulating vascular tissue development by influencing downstream genes with cis elements and DREs that function in drought stress regulation (Huang et al. 2018). The promoter regions of genes using an abscisic acid-independent pathway involved in protecting cell structures during stress have shown the presence of an essential cis element with the core sequence A/GCCGAC called the dehydration responsive element (DRE) (Kasuga et al. 2004). DREB proteins are classified into two groups, DREB1 (DREB1A, DREB1B and DREB1C) and DREB2 (DREB2A and DREB2B). Both groups have DNA binding domains that are also found in ethylene responsive element binding factor (ERF) and AP2 proteins (Priyono et al. 2013). The DREB1A gene is a transcription factor gene that plays a role in regulating a number of other genes related to drought characteristics. The DREB1A gene in rice (Oryza sativa) is a gene that plays an important role in the response to environmental stress, especially drought stress and salinity stress, by increasing the expression of genes related to stress tolerance (Santoso et al, 2012).

According to Ahmad et al (2023), the DREB gene is a transcription factor from the gene family Ethylene-responsive element binding protein (EREBP). The function of this gene family is to regulate the expression of a number of genes that are responsible for resistance to environmental stress. The DREB transcription factor, when overexpressed in Arabidopsis, is able to increase the expression of genes related to abiotic stress, thereby providing resistance to high salinity, drought and cold temperatures (Kasuga et al., 1999). Likewise, the ortholog of DREB in rice, namely

DREB1A, when over-expressed in Arabidopsis increases tolerance to high salinity, drought and cold temperatures (Dubouzet et al., 2003).

With this evidence, it can indicate the influence of the DREB transcription factor family on monocot and dicot plants. However, other opinions say that DREB1 has a conserved function in stress tolerance in higher plants (Nguyen et al, 2023). These findings offer an explanation for previous observations that stress tolerance can be enhanced by overexpressing the DREB1 gene in a heterologous system. Based on the opinion of Jan et al. (2017), the DREB1 gene acts as a junction node that connects the regulatory pathways of drought, cold and salt stress together.

DREBs constitute an important class of TFs involved in plant development and stress responses. DREB family genes are widespread and evolutionarily diverse in plants. Research by Hu et al (2022), has shown that DREB family genes have various motifs and structures in plants and participate in various functions. Under stress conditions, some cis-acting elements of gene promoters, such as hormone- and stress-responsive elements, recognize upstream signals and regulate downstream gene expression at the transcriptional level, thereby enabling plants to resist stress (Park et al, 2020). DREB TFs are sensitive to plant hormones and play a key role in plant hormone signaling pathways. DREB genes participate in hormone signaling pathways and regulate proteins that interact with downstream genes to increase plant stress tolerance (Kiselev et al, 2024). DREB is a member of the ERF family of transcription factors and regulates the expression of stress-responsive genes (cold, drought, temperature stress) through an ABA-independent signal transduction pathway (Fangming et al, 2022). In Arabidopsis, DREB/CBF specifically interacts with the dehydration/C repeat responsive element cis-active element (DRE/CRT), which controls the transcription of several stress-responsive genes. DREB1A overexpression was found to increase drought tolerance in tobacco, wheat and potato (Yang et al, 2025). Although DREB1A was shown to increase tolerance to dehydration, its constitutive overexpression is associated with growth abnormalities and thus leads to reduced crop yield (Leng, 2020 and Liu et al, 2020). This is overcome by overexpressing DREB1A under the control of a stress-inducible promoter, which reduces undesirable effects on growth and development (Filyushin et al, 2023).

2. Insertion of the DREB1 Gene in Plants

Gen DREB1 plays a role in tolerance to other abiotic stresses, especially drought resistance, Wang (2022) conducted a test to measure the survival rate of several plants with the DREB1 gene load grown in pots compared with other plants without the DREB gene load to control variability in stress treatment. The plants in the pots were 10 days old and were given heating treatment at 48°C for 2 days and then their response was measured. The measurement results show that abiotic heat stress shows that when the seeds that have the DREB gene inserted have a survival rate of 36%, while the plants without the DREB gene all die. These results indicate that the DREB1 gene is a positive regulatory gene for heat tolerance in plants (Ahmed et al, 2020 and Terletskaya et al, 2020).

The results of research from Polizel et al. (2011) showed that the insertion of a genetic construct of the DREB1A gene in soybeans would induce the expression of genes involved in drought response when plants are faced with water deficit conditions. These changes activate physiological drought response mechanisms and cause morphological changes in leaf thickness. However, a thicker abaxial epidermis may facilitate physiological adaptations in transgenic plants and serve as a barrier against excessive luminosity, heat and evapotranspiration (Islam et al, 2023). Because increasing tolerance to stress is the main goal of soybean genetic engineering, successful production of DREB1A-transformed soybean plants is very important for breeding stress-tolerant cultivars (Gunarsih et al., 2016). These results indicate that expression of DREB1A in soybean is an effective approach to improve drought tolerance. The function of the DREB1 gene in other plants has also been investigated. Several other studies have also shown something similar, where overexpression of the DREB1 gene in soybeans, cotton and rice can increase plant tolerance to heat, cold, drought and salt (Kidokoro et al., 2015; Feng et al., 2019; Zhou et al., 2020).

Research conducted by Li et. al. (2020) and Jang et al (2023) also showed how overexpression of DREB1A can increase drought tolerance in plants. DREB1A was significantly induced by drought treatment and resulted in transgenic plants overexpressing DREB1A as validated by PCR amplification and RT-qPCR. The results showed that the main root growth of transgenic plants that had overexpressed the DREB1A gene was longer than that of comparison plants without treatment (Xu et al, 2024 and Yi et al, 2023). Next, the plants are treated to test their tolerance to drought. Under conditions of lack of water for 14 days, the leaves of the comparison plants were very wilted when compared to the transgenic plants. Furthermore, the stomata openings in these two plants also show differences where the stomata openings in the transgenic plants are smaller. Likewise with the density of the stomata. After 18 days of observation, the transgenic plants showed a higher survival rate. These results indicate that overexpression of DREB1A in plants can increase drought tolerance by regulating stomata opening and density in order to control water evaporation (Bhattacharjee et al, 2023 and Jia et al 2023).

3. DREB1 Gene Expression in Plants

DREB transcription factor regulates the expression of plant stress-responsive genes through the DRE cis element. The DREB gene plays a role in increasing tolerance responses to various abiotic stresses. This is what makes DREB can be used to produce transgenic plants with tolerance to drought, high salinity or extreme drought (Caccialupi et al, 2023 and Zhao et al, 2023). The DREB1 gene has been inserted in many plants and its expression has been shown to increase stress tolerance in plants. For example: the OsDREB1A gene for freezing and high salt tolerance in Arabidopsis (Dubouzet et al., 2003), OsDREB1D for freezing and high salt tolerance in Arabidopsis (Zhang et al., 2009), OsDREB1F for salt, drought and cold tolerance in Arabidopsis and rice (Wang et al., 2008), and OsDREB1G for cold tolerance in rice (Moon et al., 2019). In addition, there are several transgenic engineered plants that use the DREB gene, including transgenic tomatoes (CBF1/DREB1B genes) which are more tolerant to water deficits (Hsieh et al. 2002). The DREB1B gene is homologous to the DREB1A gene which is responsive to low temperatures and water deficit (Gilmour et al. 1998). According to Chakraborty et al (2022), plants have the capacity to clear excessive ROS by promoting enzymatic antioxidant defense systems and the results show that the activity of these enzymes increases rapidly after 7 days of drought stress

According to Cui et al (2025), the transgenic lines showed delayed rolling and wilting symptoms compared with the wild type, which was in agreement with previous reports. This may be due to the fact that the transgenic lines maintained a higher internal water status at relatively similar levels of moisture stress (Rego et al, 2021). Reduction of leaf relative water content and stomata closure are two indicators of stress development. RWC is an index to measure tissue metabolic activity during dehydration and the level of tolerance to dehydration is positively correlated with RWC (Hai et al, 2024). In the current study, transgenic lines engineered with AtDREB1A maintained relatively higher RWC compared with non-transgenic lines reflecting a higher level of dehydration tolerance (Yongbin et al, 2023). Similar observations were noted when AtDREB1A was overexpressed in peanut and rice. Internal water loss and stomata closure are associated with increased leaf temperature affecting cellular activity. Non-transgenic plants recorded an increase of about 8 C at 18 DAIS compared to their well-watered controls, whereas transgenic lines showed an increase of only 2–3 C over their controls. This increase in leaf temperature can be associated with stomata closure and reduced transpiration (Lv et al, 2022).

Transgenic lines maintain their stomata in a partially closed state and thus maintain a minimum transpiration rate to cool the canopy and thereby reduce canopy/leaf temperatures (Shinwari et al, 2020). An increase in leaf temperature during dehydration due to increased respiration and decreased transpiration has been reported previously. DREB1A was reported to alter the metabolism of osmoprotectants such as proline and sugar accumulation during dehydration, thereby leading to increased dehydration tolerance of transgenics (Zeng et al, 2024). Through maintenance of higher RWC and open stomata may be partly due to better maintenance of turgor involving the accumulation of osmoprotectants. Through overall coordinated regulation of stomatal control, reduction of water loss, and maintenance of cell turgor (Meena et al, 2022).

According to Hou et al (2022), the OsDREB1A gene that has been transformed in rice plants shows overexpression, namely it is more tolerant of water deficits at low temperature conditions. Overexpression of the OsDREB1A transcription factor gene in rice can increase plant tolerance to salinity stress. This gene is a protein coding gene that plays a role in increasing the transcription process of genes that regulate abiotic stress including salinity (Chen et al, 2022 and Manasa et al, 2022). The research results of Xiong and Fei (2006) show that over-expression of the transcription factor gene OsDREB1A which has been integrated into Nipponbare rice is thought to activate target genes related to abiotic stress, including high salinity stress, so that Nipponbare DREB1A rice plants become tolerant. Several previous studies also showed that over-expression of the DREB1A transcription factor gene can increase the expression of target genes related to salinity resistance such as genes encoding hydrophilic proteins. This is in line with research by Santoso et al (2012), showing variations in the tolerance response of Nipponbare-OsDREB1A transgenic rice plant lines. Likewise, research by Gu et. al. (2017) showed that OsDREBIB in rice plays an important role in regulating plant responses to environmental stress in the form of drought and can protect plants from drought stress. The expression of the DREB gene against various abiotic stresses, especially drought, has been studied by several people, one of which is Khan et al (2019) who stated that the DREB2 gene was induced by high drought, thereby increasing drought tolerance in transgenic wheat.

The function of the DREB1 gene is as a transcription factor where the DREB1 gene is a protein that can bind to DNA and control the expression of other genes involved in the stress response, the DREB1 gene plays a role in the ABA (abscisic acid) independent stress tolerance pathway which means it does not require the ABA hormone to activate the stress response, DREB1 induces the expression of genes involved in the stress response such as genes that produce proteins that protect cells from damage caused by stress, DREB1 plays an important role in drought tolerance which helps plants to maintain cell moisture and reduce damage due to drought. is involved in salinity tolerance, helping plants to overcome the negative impacts of high salt levels in the soil, and the DREB1 gene has been used in genetic engineering to increase plant stress tolerance such as in transgenic rice carrying the OsDREB1A gene.

CONCLUSION

Gen DREB1 plays a role in the regulation of abiotic stress in plants. One of the abiotic stresses in plants that is regulated by the DREB1 gene is drought stress. Insertion of the DREB1 gene will induce the expression of genes involved in drought response when plants are faced with water deficit conditions. Seedlings that had the DREB gene inserted had a survival rate of 36%, while plants without the DREB gene all died. These results indicate that the DREB1 gene is a positive regulatory gene that increases plant tolerance to drought. Apart from its role in drought, DREB1 can control the expression of other genes involved in the stress response so that it does not require the ABA hormone, and is used in genetic engineering to increase plant stress tolerance.

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