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TWA1: a novel thermosensor enhancing plant thermotolerance

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In this study, *Bohn et al.* identified THERMO-WITH-ABA-RESPONSE 1 as a novel thermosensor in *Arabidopsis thaliana*. This sensor is crucial for thermotolerance and heat-stress response as it interacts with key transcription factors and co-repressors in a temperature-dependent mechanism. This discovery has the potential to significantly improve crop acclimation to global warming through biotechnological applications.

In the plant kingdom, each species has an optimal temperature range for growth and development. However, sudden climatic fluctuations or prolonged periods of intense heat can severely challenge their survival. When temperatures exceed this range, plants activate heat-stress responses (HSR) to adapt to these stressful conditions. These adaptation and response strategies involve various developmental processes in the plant[1]. Heat triggers the HSR through heat-shock factor 1 (HSF1) transcription factors, which induce the expression of heat-shock proteins (HSPs), helping the plant adapt to heat. Additionally, the HSR involves several phytohormone pathways, with abscisic acid (ABA) playing a crucial role in regulating the plant's water status, promoting thermotolerance, and enhancing plant acclimation[2,3].

To better understand the mechanisms of temperature perception and the induction of thermotolerance, *Bohn et al.* examined different lines of *Arabidopsis thaliana* that were hyper-responsive or insensitive to ABA under heat stress. Among all the mutants tested, one showed strong thermosensitivity, and the gene locus was subsequently named *THERMO-WITH-ABA-RESPONSE 1* (*TWA1*). Expressed throughout the plant, it encodes a predicted intrinsically disordered protein of 130 kDa with two potential ethylene-responsive-element-binding-factor-associated amphiphilic repression (EAR) motifs (LxLxL).

In a yeast two-hybrid (Y2H) system, TWA1 was found to interact with JASMONATE-ASSOCIATED MYC-LIKE 2 (JAM2), a transcription factor involved in jasmonate (JA) hormone signalling[4,5], and with the co-repressors TOPLESS (TPL) and TOPLESS-RELATED (TPR), forming a repressor complex. However, this interaction is highly temperature-dependent. Specifically, TWA1 only accumulates in nuclear subdomains at elevated temperatures (30-35°C), and its conformational changes allow physical interaction with JAM2 and TPL/TPR. These temperature-dependent structural rearrangements are mediated by a 20 amino acid sequence in the amino-terminal region of TWA1, defined as the Highly Variable Region (HVR). The HVR thus confers strong thermosensitivity to TWA1.

Homologues of TWA1 have been identified in both monocotyledons and dicotyledons. An interesting aspect is the role of HVR in thermal sensing, particularly its amino acid sequence. Although they have comparable inhibitory effects at 30-35°C, their thermal sensitivity or temperature threshold varies. For instance, half-maximum inhibitory values (IT_{50}) of 20°C, 26°C, and 30°C were observed for TWA1 in *A.lyrata* (cold acclimated), *A.thaliana*, and *Sinapis alba* (Mediterranean climate), respectively. Similarly, this threshold has been shown to affect accumulation and interaction with JAM2 and TPL and, consequently, the activation of its inhibitor effects.

Moreover, tests involving the overexpression of TWA1 (TWA1(oe)) have demonstrated its ability to confer an enhanced thermotolerance, both basal and acquired, without impacting growth and photosynthesis. No significant differences in growth, photosynthesis, and gas exchange were observed between WT and TWA1(oe) when grown at 20°C. These findings reconfirm the activation of TWA1 only above specific temperatures. Additionally, the improved thermotolerance of TWA1 is not due to the constitutive upregulation of HSP transcripts.

TWA1 presents an interesting parallel with other known thermal sensors, such as EARLY FLOWERING 3 (ELF3) in *A.thaliana*[6]. However, thermally, TWA1 acts oppositely to ELF3, repressing gene expression at high temperatures and being much more sensitive to temperature changes.

In conclusion, *Bohn et al.* have identified a new thermosensor, TWA1, and demonstrated its requirement for thermotolerance and the transcriptional upregulation of HSFA2 and HSPs in *A.thaliana*. The potential of TWA1 in breeding and biotechnology is vast, providing valuable tools for enhancing crop acclimation to the growing issue of global warming. Additionally, TWA1 and its orthologues represent a valuable resource in the emerging field of thermogenetics[7].

HSR, heat-stress responses • **HSPs,** heat-shock proteins • **ABA,** abscisic acid • ***TWA1,*** *THERMO-WITH-ABA-RESPONSE 1* • **Da,** Dalton • **EAR,** ethylene-responsive-element-binding-factor-associated amphiphilic repression • **Y2H,** yeast-to-hybrid • **JAM2,** JASMONATE- ASSOCIATED MYC2-LIKE 2 • ***TPL,*** *TOPLESS* • ***TPR,*** *TOPLESS-RELATED* • **HVR,** highly variable region • **TWA1(oe),** TWA1-overexpressed • **ELF3,** EARLY FLOWERING 3 • **HSFA2,** heat-shock transcription factor A2.

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