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Invited review

Stress responsive DEAD-box helicases: A new pathway to engineer plant stress tolerance

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Abstract

Abiotic stresses including various environmental factors adversely affect plant growth and limit agricultural production worldwide. Minimizing these losses is a major area of concern for all countries. Therefore, it is desirable to develop multi-stress tolerant varieties. Salinity, drought, and cold are among the major environmental stresses that greatly influence the growth, development, survival, and yield of plants. UV-B radiation of sunlight, which damages the cellular genomes, is another growth-retarding factor. Several genes are induced under the influence of various abiotic stresses. Among these are DNA repair genes, which are induced in response to the DNA damage. Since the stresses affect the cellular gene expression machinery, it is possible that molecules involved in nucleic acid metabolism including helicases are likely to be affected. The light-driven shifts in redox-potential can also initiate the helicase gene expression. Helicases are ubiquitous enzymes that catalyse the unwinding of energetically stable duplex DNA (DNA helicases) or duplex RNA secondary structures (RNA helicases). Most helicases are members of DEAD-box protein superfamily and play essential roles in basic cellular processes such as DNA replication, repair, recombination, transcription, ribosome biogenesis and translation initiation. Therefore, helicases might be playing an important role in regulating plant growth and development under stress conditions by regulating some stress-induced pathways. There are now few reports on the up-regulation of DEAD-box helicases in response to abiotic stresses. Recently, salinity-stress tolerant tobacco plants have already been raised by overexpressing a helicase gene, which suggests a new pathway to engineer plant stress tolerance [N. Sanan-Mishra, X.H. Pham, S.K. Sopory, N. Tuteja, Pea DNA helicase 45 overexpression in tobacco confers high salinity tolerance without affecting yield. Proc. Natl. Acad. Sci. USA 102 (2005) 509–514]. Presently the exact mechanism of helicase-mediated stress tolerance is not understood. In this review we have described all the reported stress-induced helicases and also discussed the possible mechanisms by which they can provide stress tolerance.

Keywords: ABA; Abiotic stress; Biotic stress; Cold shock proteins; DEAD-box protein; DNA helicase; Plant helicases; RNA helicase; Ribosome; Signal transduction; Stress tolerance; UV radiation

Contents

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1. Introduction

Population of the world is increasing at a frightening rate and may reach close to 9 billions by the year 2050 (US Census board). On the other hand crop yield is reducing due to the effect of various environmental stresses. In future it will be difficult to meet the increasing demand of food; therefore it is now essential to develop the stress-tolerant varieties [1,2]. Plants are subject to a variety of stresses and show a rapid molecular response to changing environmental conditions such as extreme temperature, UV-B radiation, drought and salinity, etc. Usually exposure to low temperature results in mechanical constraint, whereas drought and salinity disrupt the ionic and osmotic equilibrium of the cell. The stress signal is first perceived at the membrane level by the receptors and then transduced into the cell, which results in activation of various stress-responsive genes to provide stress tolerance (Fig. 1). After this a large and complex signaling cascade is activated. The products of these stress-responsive gene may provide the stress tolerance either directly or indirectly (Fig. 1), which ultimately lead to plant adaptation and help the plant to survive and surpass the stress conditions. Plants can respond to stress as individual cells or as a whole organism. Understanding the mechanism of stress tolerance along with large number of genes involved in stress signaling network is important for crop improvement. Recently, some genes of nucleic acid pathways including helicases have been reported to be upregulated in response to both cold and salinity stresses indicating their involvement in stress signaling [1–3].

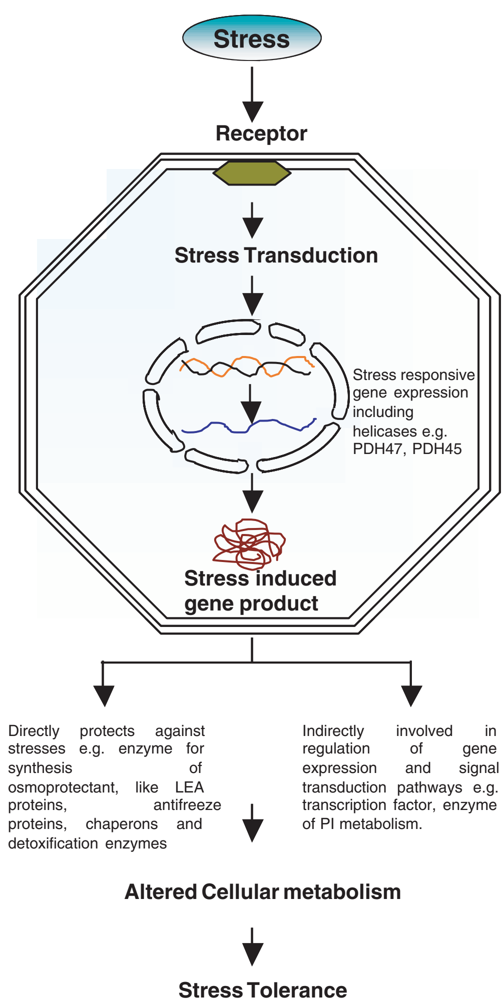

Fig. 1. Schematic view of change in cellular profile after stress perception. With the help of receptor a plant cell perceive the stress stimuli. After this a large and complex signaling cascade is activated. This signaling cascade results into the expression of stress-responsive genes. The products of these stress-responsive gene may provide the stress tolerance either directly or indirectly.

In general, living organisms contain stable genomes, but due to constant exposure to various environmental agents, the DNA gets damaged, which leads to genome instability. The man made pollutants are responsible for depleting the stratospheric ozone layer, which causes the increased exposure to solar UV-B (315–280 nm) radiation. Plants and animals are most affected by UV-B radiation from sunlight, which penetrates and damages their genome by oxidative damage and cross-links, resulting in retardation of growth and development. Usually organisms respond to genome damage by activating a network of DNA repair enzymes including helicases. These repair helicases help in opening the damaged area of duplex DNA, which is required for repair processes. The genes for repair helicases in plants have been reported now.

In this review we have emphasized on various aspects of stress, DNA and RNA helicases including stress-responsive helicases and the possible mechanisms of helicase action during stress.

2. Stress

Before describing about stress, it is important to know what is ‘stress’? According to engineers and physical scientists stress is a mechanical concept, which is defined as a force per unit area applied to an object. Due to the stress,