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The role of Osmotin Protein Tolerance to Biotic and Abiotic Stress in Plants

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Abstract

Osmotin is a stress responsive cytotoxic protein belonging to the pathogenesis- related (PR)-5 family that confers tolerance to both biotic and abiotic stresses in plants. Osmotin plays an important role in development of transgenic like tobacco, potato, strawberry, tomato. This review focuses on the role of osmotin in different conditions of environmental stress and microbial infections. It also discusses about some ongoing researches to improve the role of osmotin in other aspects considering human health.

Keywords: Cytotoxic, pathogenesis related proteins, osmotin, stress responsive, antifungal, osmotin like proteins, transgenics.

Plants are subjected to various kinds of biotic Abad L *et al.* (1996) and abiotic stresses Abdin M. (2011) during different developmental phases. Due to stress, there is a loss of cellular activities which accounts to reduced growth and loss of yield. But plants can sense and respond to these different stresses that are complex and integrative. Plants are constantly being challenged by different pathogens, but the damage caused by the pathogen often remains restricted as a result of activation of defence responses. Those responses are associated with a coordinate and integrated set of metabolic alterations that include various proteins, which are collectively referred to as pathogenesis- related proteins (PRs). PRs are activated when the plants are exposed to microbial attack, a cascade of signals are generated with protein domains homologous to those encountered in animal immune response.

PR proteins are accumulated by the plants in response to pathogen invasion and other signals as final products of a plant defence response Agaoglu Y. (2004). Several resistance "R" genes have been identified in plants which participate in signal transduction pathway after accounting pathogen attacks. These plant genes encode defensive proteins, including osmotin. But the mechanism via which these proteins are activated and how they function are yet not known. PR-5 proteins induce fungal cell leakiness, presumably through a specific interaction with the plasma membrane Aghaei K. (2008). Osmotin and osmotin like proteins also play a crucial role in osmotic stress.

Osmotin is a multifunctional stress responsive PR-5 protein is named on the basis of its induction by osmotic stress to lower potential Aliprantis A. *et al.* (1999). Osmotin and its homologous proteins are ubiquitous in most fruits and vegetables. Osmotin and OLPs confer stress tolerance to plants and their expression was induced by NaCl Anssour S *et al.* (1998), ethylene Apse M.P. *et al.* (2002), dessication

Arsenescu V., *et al.* (2011), cold Aslam M., *et al.* (2009), drought Atkinson N. *et al.* (2012), salicyclic acid Barthakur S., (2001), wounding Batalia M. (1996), fungal, bacterial, viral diseases. Osmotin shows tissue-specific activity with ABA, ethylene, and NaCl treatments Bhattacharya A., *et al.* (2006). Osmotin like proteins also show tissue specific expression in plants. Under oxidative stress conditions, OLPs are expressed in the quiescent region of root apex and meristematic region of shoot apex Bobbert T *et al.* (2005).

Osmotin as a plant antifungal protein

Several resistance "R" genes have been identified whose products participate in transduction of signals from pathogens leading to the activation of plant genes encoding defensive proteins, including osmotin. It has been found from the report (Bodles A.M., *et al.* (2006) that osmotin stimulates a mitogen-activated protein kinase (MAPK) signal system in yeast to induce changes in the cell wall that enhance cytotoxicity of this antifungal protein.

The genes STE4, STE18, STE20, STE5, STE11, STE7, FUS3, KSS1, and STE12 are required for full sensitivity to osmotin. Osmotin induces signal flux through STE7; deletion of any of these genes results in altered cell wall permeability to osmotin. Osmotin, to enhance its toxicity, activates a MAPK cascade whose stimulation results in changes in the cell wall that facilitate osmotin access to the plasma membrane. Since mutation of the genes encoding the G-protein *b* and *g* subunits, the MAPK module, and STE12 increased resistance to osmotin without blocking cell death completely, and spheroplasts of the MAPK cascade mutants were as sensitive to osmotin as isogenic wild-type yeast, it is proposed that cell death ultimately results from a different set of interactions of osmotin with the plasma membrane.

The precise mechanism by which osmotin activates a MAPK pathway remains unclear. Osmotin may subvert the mating pathway and induce only a subset of the mating-specific responses, such as those involved in cell wall abrogated the osmotin tolerance conveyed by cell wall alteration in preparation for cell agglutination and fusion.

One possibility can be drawn-osmotin activates the MAPK pathway in a manner independent of the pheromone receptors and GPA1 by interacting with downstream components in some way. It can be postulated that osmotin activates pathway intermediates after interaction with the plasma membrane, perhaps involving cytoplasmic internalization.

Osmotin and Osmotic stress

Osmotin-like proteins are encoded by at least six members of a multigene family in *Solanum* commersonii. A genomic clone (ApCEM2a-7) that contains two osmotin-like protein genes (OSML13 and OSML81) arranged in the same transcriptional orientation has been isolated. Transcriptional activation of OSMLl3 and OSML8l promoters has been studied by the 5′ flanking DNA sequence (-1078 to +35 of OSML13 and -1054to +41 of OSML81) was fused to the beta-glucuronidase (GUS) coding region, and the chimeric gene fusions were introduced into wild potato (*S. commersonii*) plants via Agrobacterium mediated transformation. Analysis of the chimeric gene expression in transgenic potato plants showed that both 5′ flanking DNA sequences are sufficient to impart GUS inducibility by abscisic acid, NaCI, salicylic acid, wounding, and fungal infection. Low temperature activated both chimeric genes only slightly. lnfection with *Phytophthora* infestans resulted in strong GUS expression from both chimeric genes primarily in the sites of pathogen invasion, suggesting a limited diffusion of fungal infection-mediated signals. It has been demonstrated that tobacco osmotin gene expression is activated by ABA, NaC1, wounding, viral infection, and ethylene.

There are at least six members of osmotin-like protein genes in potato. Two of them have been isolated from a *S. commersonii* genomic library using the previously characterized pA13 cDNA as a hybridization probe. From the report Bol J. *et al.* (1990)there is a possibility that the promoter regions of these two genes contain similar cis-acting elements. Indeed, it was found that there are at least five DNA sequences conserved in these two promoters as well as in a tobacco osmotin gene promoter. Promoter sequences of both osmotin-like protein genes along with the tobacco osmotin gene were searched for specific cis-acting elements that may function in the activation of PR genes. A 5′-GGCGGC-3′ motif conserved in the 5′ upstream sequences of some ethylene-inducible PR genes was found in these three genes. Both promoters of potato osmotin-like protein genes are wound inducible. It is possible that the wound inducibility of osmotin-like protein genes is mediated through ethylene, as seen for a tobacco osmotin gene promoter. In addition, ABA is most likely involved in wound-induced gene activation of OSMLl3 and OSMLSl.

Analysis of potato transgenic plants carrying copies of OSML13::GUS or OSML81::GUS showed comparable GUS expression patterns in response to various stimuli. Whether the conserved DNA sequences are responsible for these comparable expression patterns remains to be determined by 5′ deletion and mutation analysis. ABA, SA, NaCl, wounding, and fungal infection regulate the expression of osmotin-like protein genes primarily at the leve1 of transcription. When exposed to low temperature, transgenic potato plants exhibited little increase in GUS activity, consistent with the results from RNA gel blot analyses with OSML13 and OSML81 gene specific probes.

These results suggest that the observed increase in osmotin-like protein mRNA abundance during a long period of cold acclimation is due either to post-transcriptional regulation or expression from different genes. Low-temperature treatment has been demonstrated to regulate cor (cold regulated) gene expression through both transcriptional and post-transcriptional means. Recently, a *leu* (late embryogenesis 3bundant)-type mRNA has been shown to be only stabilized but not induced by low temperature.

Conclusion

Osmotin or osmotin like proteins are a boon to the plants. These proteins have dual function of preventing the plants from the various kinds of stress and also from the pathogen attack.

Osmotin are of great usage in uplifting the yield of various crops in different regions where generally yield is less due to abiotic stress. These proteins on being engineered can solve many problems related to the crop production. Late blight of potato has been overcome with the proper application of osmotin. Large numbers of transgenic plants can be produced in a much shorter time in this species than in the cultivated potato (*Solanum* tuberosum).

Osmotin, a naturally occurring plant protein mimics human adiponectin. Osmotin shares structural and functional homology with adiponectin and not sequence similarity. Osmotin, a multifaceted plant protein confers tolerance to both biotic and abiotic stresses. Adiponectin, an antidiabetic and anti atherosclerotic protein is reduced in obese patients and leads to several diseases including coronary artery disease, inflammation, and liver diseases. Osmotin shows homology with human hormone adiponectin given that osmotin not only induces AMP kinase phosphorylation in mammalian C2C12 myocytes via AdipoRs, but also binds to the AdipoR1 by activating the same signalling path of adiponectin. Osmotin and adiponectin involve in anti-tumor activity byinhibiting p53 and suppressing caspase activity. In vitro and animal model studies suggest that, like AdipoRon and pioglitazone, osmotin acts as agonist for adiponectin. Due to the multiple activities of osmotin, it can be explored as an attractive option as agonist for adiponectin in treating adiponectin deficiency diseases in humans besides its function in biotic and abiotic stress tolerance in crop plants.

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