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Research Article

Snapshot of the Involvement of Glutathione in Plant-Pathogen Interactions

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Glutathione (GSH), a dynamic biomolecule, is popularly called the "master antioxidant". This tripeptide thiol is almost ubiquitously found in prokaryotes, and eukaryotes, with some organism exceptions, and is known for its several significant roles including in plants. GSH in plant systems restricts itself not only to plant growth and development but its role is crucial in providing resistance to plants against several environmental hazards also.

The potential of GSH in environmental stress management in plant systems is an indisputable fact. The present article opines and articulates a few of the major research findings elucidating the role of glutathione in imparting resistance to different model and non-model plant systems against several phytopathogens. Numerous reports on the involvement of glutathione in inducing plant defense genes along with the increase in GSH and related enzymes are present that relate to its role in plant defense against diverse biotic challenges including pathogens like bacteria, fungi, and plant viruses. Glutathione, the core regulator in biotic stress management, shows significant alterations in its level upon pathogen invasion. The resulting enhanced GSH/GSSG ratio activates pathogen-defense pathways and downstream signaling cascades. One of the prime mechanisms by which GSH can be linked to its regulation of biotic stress reactions involves redox signaling. For activating plant defense and developing resistance towards pathogens, GSH and ROS play significant roles, but within different cellular compartments. ROS and GSH mediate plant defense in the cytosol and nuclei. Upon pathogen ingress, ROS and GSSG that are generated in the separate organelles, either get diffused or gets transported back to the cytosol. Glutathione mainly protects plants from oxidative damage by keeping ROS under control during compatible plant-pathogen interaction [1]. Further, the contribution of glutathione in the activation of plant immune response against pathogen attack is marked by its substantial role in the cross-talk with several phytohormones in the plant defense signaling network. Thus, changes in the redox state of glutathione and ROS accumulation in cytosol lead to the initiation of defense genes in nuclei through pathways involving phytohormones thereby providing resistance to plants against pathogens. Some of these well-established phytohormones and stress modulators include salicylic acid (SA), jasmonic acid (JA), ethylene (ET), HSPs, MAPKs, etc. GSH which exhibits an interplay with these molecules in different plant species in response to various pathogen attacks, has been documented to activate specific defense-related genes. In one study using transgenic tobacco, GSH has been demonstrated as a signaling molecule and alleviating biotic stress against the biotrophic pathogen *Pseudomonas syringae*, through a non-expressor of PR genes 1 (NPR1)-dependent SA-mediated pathway [2]. Similarly, transgenic tobacco with enhanced GSH content demonstrated the GSH-ET interplay in providing resistance against phytopathogen exhibiting up-regulation and up-accumulation of ET-related transcripts and proteins like ACO, ERF4, WRKY1, and ACC synthase (ACS), ACO respectively [3]. Different studies have demonstrated a lucid relationship between increased GSH concentration and pathogen interactions [4-6]. Also, the redox state of glutathione, along with the availability of its precursors marks the variation of different plants' response to different classes of phytopathogens [6]. Exogenous GSH application to cultured plant cells like *Phaseolus vulgaris* L., *Glycine max* L., and *Nicotiana tabacum* L., activated and stimulated transcripts encoding pathogen defence-related proteins which are involved in the production of lignin and phytoalexin viz. phenylpropanoid

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pathway genes, PAL, chalcone synthase (CHS) [7,8]. Induction of accumulation of GSH has been reported both in plants [9] and cell cultures [10,11] after treatment with pathogen-derived elicitors. One significant research highlighted how a mutant line of *Arabidopsis thaliana* named phytoalexin-deficient (pad) mutants that have only 22% of GSH content, exhibited increased susceptibility to the bacterial plant pathogen *Pseudomonas syringae*, thus supporting the role of GSH in plant defence at the genetic level [12] and proteome level [13]. Similar susceptibility of this mutant line to fungal phytopathogens like *Phytophthora porri* and *Botrytis cinerea* have also been reported [14,15]. While studying the GSH-ET interaction at the molecular level in another investigation of ours, the regulation of ET biosynthesis was shown to be induced by GSH in a dual way via both transcriptional and posttranslational regulations against *Botrytis cinerea* infection [16]. One study using *Nicotiana tabacum* L. plants and its transgenic counterpart exhibiting high-glutathione lines (HGL) against *Pseudomonas syringae* pathovars, suggested that although mitogen-activated protein kinase (MAPK) and SA signalling could operate independently, both were modulated by GSH against the pathogenic infection [17]. Similar findings in another research study analysed GSH-fed samples of each of *Arabidopsis thaliana* control and transgenic line over-expressing *LeMPK3* gene (*AtMPK3* line) along with MPK3-depleted mutants against *P. syringae* infection. Results showed how GSH regulates mitogen-activated protein kinase-mediated resistance against this phytopathogen [18].

In conclusion, the crucial role of GSH involved in plant-pathogen interaction thereby providing resistance to plants and aiding them to adapt to the biotic environment can be deciphered from this brief report.

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