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Role of Polyphenols and their Derivatives in Abiotic Stress Management

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INTRODUCTION

Polyphenols are secondary plant products or secondary metabolites, naturally synthesized in plant and involved in the several defense mechanisms. They are frequently distributed throughout the plant kingdom as phenolic compounds, flavonoids, lignin, and stilbenoids. Polyphenols are the largest group of secondary plant products includes more than 8000 types of molecules from different groups (Zavaleta, et al., 2003). Generally polyphenols are biosynthesized through shikimate and phenylpropanoid pathway that produces a wide array of monomeric and polymeric polyphenols (Kumar, 2016). Most of the phenolic compounds naturally synthesized in the plants are organic compounds with one or more functional group attached with benzene ring (Sharma, et al., 2019). Flavonoids are complex phenolic compound consists of 15–C compound with basic carbon skeleton C_6–C_3–C_6. They have two benzene ring at left and right side and designated as A and B ring. Lignins are highly branched structure and expressed as polymer of phenolic compound with basic carbon skeleton C_6–C_3 (Linic, et al., 2019).

Under unfavorable environmental conditions, naturally biosynthesized polyphenols play crucial physiological role throughout the plant life cycle in response to stress management. It has been observed in the several cases, the phenylpropanoid biosynthetic pathway is activated under acute environmental conditions like drought, high temperature, soil salinity, and heavy metal pollution with accumulation of various kinds of the phenolic compounds. When plants subjected to environmental stressed condition, the sessile organism of the plants respond to stress condition with change in the patter of gene expression of the particular proteins that control the biosynthesis of secondary metabolites involved in the development of interactions between plants and surround environments (Gonzalez-Sarrias, et al., 2020).

2. Phenolic acid

Phenolic acid the diverse group of plant secondary metabolites associated with benzene ring and most of them are found in conjugated form. Most of the phenolic acids found in the plants are structural components of the plant cell like cellulose, lignins and proteins (Andreasen, et al., 2000). They are also associated with some smaller molecules like glucose, malic acid, tartaric acid, and quinic acid (Lam, et al., 2001). They are rarely found in the free form. On the basic of structural organization and plant derived phenolic acids are classified in to two major categories of hydroxybenzoic acid and hydroxycinnamic acid.

2.1. Hydroxybenzoic acids: Hydroxybenzoic acid has C_6–C_1 carbon skeleton, derived from benzoic acid. Hydroxybenzoic acid produces several types of acids like salicylic acid, vanillic acid and gallic acid (Goleniowski, et al., 2013). Other derivatives of hydroxybenzoic acids are 2-3-DHBA, 2-5-DHBA, 3-4-DHBA, 3-5-DHBA. Diversity in the derivatives of hydroxybenzoic acids are due to variation in the structure results from methylation and hydroxylation of aromatic ring (Macheix, et al., 1990). Hydroxybenzoic acids naturally synthesized in the plants are working as potent antioxidants under abiotic stressed condition (Bistgani, et al., 2019). Under acute drought and high temperature condition, hydroxybenzoic acid derivatives can medicate the scavenging of harmful reactive oxygen species (ROS) and develop survival mechanism (Chen, et al., 2019). Furthermore, the antioxidant system inside the plants accelerates the stimulation of phenylpropanoid biosynthetic pathway, inducing synthesis of phenolic acids (Al-Ghamdi and Elansary, 2019).

2.2. Hydroxycinnamic acids: Hydroxycinnamic acid has basic carob skeleton C_6–C_3 and derived from cinnamic acid. Caffeic, ferulic, sinapic acids, and p-coumaric acids are the major derivatives of hydroxycinnamic acid (Shahidi and Naczk, 2004). Most of the conjugate forms of the hydroxycinnamic acids are the esters of hydroxyl acid like quinic, shikimic, and tartaric acid (Strack, 1997). Accumulation of hydroxycinnamic acids has been recorded in many plants under high temperature and water deficit condition (Mahdavi, et al., 2015). The antioxidant potential and role of polyphenolic derivatives in stress response in plants has been investigated for different types of stress. Furthermore, the gallic acid with ellagic acid provides protection to the plants against microbial pathogens, harmful insects, and other herbivores (Buzzini, et al., 2008).

3. Flavonoids

Flavonoids are highly diverse group of phenolic compounds with more than 6000 types of derivatives biosynthesised in both normal and stressed condition. On the basis of structural configuration, flavonoids are designated as flavonols, flavones, flavan-3-ols, isoflavones, flavanonols, flavanones, and anthocyanins. All the derivatives of flavonoids have central heterocyclic ring in their structure (Panche, et al., 2016). Most of the flavonoids biosynthesized in the plants are found in free form, they are not associated with other molecules. In most of the biological process performed by plants with respect to flavonoids are antioxidant activities as summarized by Williamson et al. (Williamson, et al., 1999). Flavanones are the important chemicals synthesized in the citrus plants play crucial role against number of stresses. In tomatoes, heat stress induced the accumulation of naringenin and naringenin chalcone, whereas under salinity or the combination of salinity and heat, the same compounds were down-regulated compared to the control (Martinez, et al., 2016). They are also involved in the several mechanism associated with biotic interactions. Another important group of flavonoids are isoflavones, biosynthesised by leguminous plants. Several studies have reported that the naturally synthesized isoflavones in leguminous protects plants from several abiotic threats like low temperature,

drought and soil salinity (Swinny, et al., 2005). Several studies that focused on flavan-3-ols levels under drought stress reported reduced levels of flavan-3-ols in Juvenal plants (Aranda, et al., 2018).

4. Stilbenoids

Stilbenoids are the secondary phenolic compound biosynthesized by plants as stilbene. The basic skeleton of stilbenoids are consists of two aromatic ring jointed by methylene bridge. The stilbenoids synthesized in plants release stilbene synthase enzyme. The enzyme stilbene synthase accelerate the antifungal, antibacterial, and antiviral activity inside the plants and protects from insects, pests and diseases are well documented (Hasan and Bae, 2017; Billet, et al., 2020). Stilbenoids are also involved in the development of tolerance in plants when subjected to water deficit and temperature stress (Fang, et al., 2020).

5. Lignans

Lignans are the largest group of non-flavonoid compound widely distributed in the vascular plants. They are associated with two propenylphenyl units with different degree of oxidation (Teponno, et al., 2016). Most of the lignans naturally synthesized in the plants are found in free form and play crucial role in the development of tolerance against number of abiotic threats. Lignans are the important phenolic acid involved in the various kinds of abiotic stress management (Bhardwaj, et al., 2013). They are involved in the chilling stress tolerance mechanism through increasing the number of polyphenols like lignans. In several studies it has been observed that, the naturally synthesized polyphenols protects tobacco, tomato and potato plants from various cope of low temperature (Paniagua, et al., 2017).

CONCLUSION

Most of the abiotic threats are usually associated with increased level of secondary plant products, particularly polyphenols. The polyphenols, naturally synthesized in the plants are involved in the survival mechanism when plants subjected to unfavourable environmental condition. However, the antioxidant activities of most of the polyphenols and their derivatives provide strength to the plants in response to unfavourable environmental conditions like drought, salinity, and temperature stress. On the behalf of literature available, most of the polyphenols including phenolic acids, flavonoids, lignans, and stilbenoids involved in protective mechanism. The future study of the polyphenols in abiotic stress management requires multidisciplinary approach as well as metabolomics approaches for better understanding about the activity of phenolic compounds.

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