AgriCos e-Newsletter
ISSN: 2582-7049
Volume : 01 Issue : 03 July 2020 Article No: 52

Abiotic Stresses in Plants: Important Secondary Metabolites

Aditya Pratap Singh [1] and Yengkhom Linthoingambi Devi [2]
[1] Department of Genetics and Plant Breeding, BCKV, Mohapur-741252, West Bengal, India
[2] Department of Genetics and Plant Breeding, IGKV, Raipur-492012, Chhatisgarh, India

SUMMARY

Plants undergoing environmental stresses synthesise varied range of secondary metabolites. These are mostly polyamines and polyphenolic compounds which directly or indirectly help in resilient behavior of the plants. Thousands of such compounds have been characterized and studied but functions of many are still unknown. The information about their synthesis pathways and functions can open up scope for stress resilient cultivar development through approaches like gene manipulation etc.

INTRODUCTION

Stresses, both biotic and abiotic are major hurdles in attaining potential crop yield worldwide. Establishing an approach for achieving higher crop yields under stress conditions is a major challenge as well as goal for researchers and stakeholders alike. As have been pointed out, present achievements of crop productivity have mainly relied upon management practices that have led to degraded land and water systems (FAO, 2011). Ever-increasing demographic demand along with alteration in weather patterns due to climate change are adding up to the limitations. Biotic stresses, primarily crop diseases are significant constraint to production of over 25 important food and fiber crops. Among abiotic stresses, drought, water logging, salinity and heavy metal accumulation adversely affect productivity and growth of crops. To develop an approach for sustaining crop productivity, it is of paramount importance to understand plant responses to these stresses that disturb the homeostatic equilibrium at cellular and molecular level. A common mechanism for multiple stress tolerance can be identified thereafter. Plants synthesize secondary metabolites from primary metabolites such as carbohydrates, lipids and amino acids which are then utilized to confer protection against environmental stresses and plant defence against herbivores and pathogens. These secondary metabolites play a major role in the adaptation of plants to environment and in overcoming stress conditions. However, we will be discussing only the relationship between stresses and secondary metabolites in crop plants.

Environmental Factors Influencing Secondary Metabolites

Secondary metabolites in do not directly involve in growth and development but they serve essential role in the plants' life events. More than hundred thousand of such metabolites have been discovered and the list keeps extending everyday but characterization has been done for only few of them. Environmental factors like high and low temperature, drought, alkalinity, salinity and UV light are known to increase the accumulation of phenyl-propanoids which are involved in protective functions. The concentrations of various secondary metabolites are strongly dependent on the growing conditions and have impact on the metabolic pathways responsible for the accumulation of the related natural products. Stresses caused by UV irradiation-excess and intense light induce the production of phenolics and carotenoids while nutrient stress cause rise in phenolic levels. Exposure to drought or salt stress causes reactions in plants leading to cellular dehydration causing osmotic stress and removal of water from the cytoplasm to vacuoles. Deficiencies in nitrogen and phosphate directly influence the accumulation of phenyl-propanoids. Sulfur, potassium, and magnesium deficiency are also reported to increase phenolic concentrations. Low iron level can cause increased release of phenolic compounds from roots. Calcium levels have been implicated in plant response to many abiotic stresses including cold, drought and salinity. Expression levels of certain genes have been shown to increase in response to reactive oxygen species, low temperature, high temperature and osmotic stress. Formation of phenylamides and significant accumulation of polyamines in bean and tobacco under the influence of abiotic stresses were reported suggesting antioxidant role of these secondary metabolites. Similarly, anthocyanin accumulation is stimulated by various environmental stresses such as UV, blue light, high intensity light, drought, sugar and nutrient deficiency. Salinity often leads to both ionic as well as osmotic stress in plants, resulting in accumulation or decrease of specific secondary metabolites. Anthocyanins are reported to increase in response to salt stress. In contrast to this, salt stress decreased anthocyanin level in the salt-sensitive species. It has been established that salt tolerant alfalfa plants rapidly double their proline content in roots, whereas in salt sensitive plants the increase was slow. A correlation between proline accumulation and salt tolerance in tomato (*Lycopersicon esculentum*) and black mangrove (*Aegiceras corniculatum*) has also been found. In tomato cultivars under salt stress, endogenous Jasmonic Acid was found to accumulate. Increase in polyphenol content in different tissues under increasing salinity has also been reported in a number of plants. Navarro *et al.* (2006) showed increased total phenolics content with moderately saline level in red peppers. Plant polyamines have been shown to be involved in plant response to salinity. Salinity-induced changes of free and bound polyamine levels in sunflower (*Helianthus annuus* L.) roots were reported. Glycine betaine plays an important role as a compatible solute in plants under various stresses, such as salinity or high temperature.

Phenolic Compounds

Phenolic metabolites constitute the most diverse group of secondary metabolites found in plants and includes phenylpropanoids (cinnamic, coumaric, caffeic and ferulic acids) and their derivatives such as polyphenolics, namely flavonoids, anthocyanins and tannins. These compounds are synthesized *via* the shikimate pathway leading to phenylanaline, the substrate for phenylalanine ammonia lyase (PAL) which is the key enzyme in the phenolic biosynthesis pathway. This enzyme catalyzes deamination of phenylalanine giving rise to cinnamic acid, the first precursor of flavonoid and lignin biosynthesis. Under adverse environmental conditions, the increase in PAL activity and other enzymes of the phenylpropanoid pathway has been reported. This is of relevance in a climate change context, in which it is expected that the ambient CO_2 concentration rises considerably. *Brassica rapa* plants subjected to increased CO_2 (744 ppm, about 2-fold the current ambient levels) concentrations for more than 40 days increased trichome density as well as the amount of constitutive phenolics. In *Arabidopsis thaliana*, UV-B treatment increased the concentration of flavonol (naringenin, kaempferol and quercetin hexosides) and derivatives (cinnamoyl and coumaroyl) that may act as UV-B radiation screen. In response to soil flooding, more than 40 flavonoid in leaves of two citrus rootstock species differing in stress tolerance were identified. After metabolite profiling analysis of samples from flooded and control plants, it was found that flavonoid levels were reduced to a greater extent in the sensitive genotype compared to the tolerant type, suggesting an efficient redox balance in the tolerant species. Phenylpropanoids are precursors of lignins, which constitute an important stress defense mechanism, especially at the root level where they can modulate cell wall composition and stiffness. Other phenylpropanoids derived from the isochorismate pathway collectively known as benzenoids are found as volatile forms, esterified to other secondary metabolites or bound to cell wall .A well-known benzenoid is salicylic acid (SA), a plant hormone that has been traditionally involved in pathogen defense but has also been found effective in reducing the damage induced by several abiotic stress conditions. Mechanistically, SA may induce little bursts of H_2O_2 production resulting in mild oxidative stress which, in turn, could enhance the antioxidant activity, improving stress tolerance.

Glucosinolates

Glucosinolates, a group of nitrogen and sulphur-containing compounds derived from aminoacids such as methionine, alanine, valine or leucine (aliphatic); phenylalanine or tyrosine (aromatic) and tryptophan (indolic glucosinolates) are known to respond to different abiotic stress conditions under stress-specific basis. Drought and soil waterlogging have been found to induce aliphatic glucosinolates and flavonoids but their actual function in abiotic stress tolerance is yet to be found.

Carotenoids and Other Terpenoid Derivatives

Carotenoids, xanthophylls and others like α-tocopherol exert a positive effect against heat stress through the stabilization of the lipid phase of the thylakoid membranes. These compounds protect the plants against the damaging effects of high intensity light and UV radiation. However, the role of carotenoids is not restricted to UV radiation protection alone. Under stress conditions, the over-expression of phytoene synthase gene in transgenic tobacco plants has been found to improve osmotic and salt stress tolerance by channeling carotenoid flux to ABA biosynthesis which led to increased levels of this phytohormone.

CONCLUSION

The most typical traits found in drought tolerant types are changes in phenylpropanoids leading to differential flavonoid profiles. Higher concentrations of phenylpropanoids such as caffeoylquinic acid and phenylalanine are found in drought tolerant genotypes while sinapic acid and flavonoids such as quercetin are higher in sensitive species. In tomatoes, water stress has an influence on the chemical composition of fruits depending on the relative sensitivity or tolerance of plants. Fruits of the drought-sensitive cultivar “Josefina” showed a significant decrease in hydroxycinnamic acids and flavonoid glycosides in response to water deficit whereas tolerant “Zarina” did not show such a response. However, grafting of the sensitive cultivar on the tolerant one had a positive effect on metabolite content of fruits after stress treatment, indicating that this could be an efficient tool to improve crop quality even under water deficit condition. The complex interaction between genotype and environment along with the fact that metabolites integrate these two components has favored an increasing tendency to use metabolites as selection markers in crop breeding programs. In this context, a good deal of efforts has been oriented to cultivar selection, rootstocks and varieties with improved tolerance to yield- and quality-limiting stress factors.

REFERENCES

FAO (2011). The state of the world´s land and water resources for food and agriculture (SOLAW) - Managing systems at risk. *Food and Agriculture Organization of the United Nations*, Rome and Earthscan, London.

Tiwari S, Lata C, Singh Chauhan P, Prasad V, Prasad M (2017). A functional genomic perspective on drought signalling and its crosstalk with phytohormone-mediated signalling pathways in plants. *Curr Genomics* 18(6):469–482.

Aziz A, Martin-Tanguy J, Larher F. (1998). Stress-induced changes in polyamine and tyramine levels can regulate proline accumulation in tomato leaf discs treated with sodium chloride. *Physiol Plant.* 104:195–202.Chalker-Scott L, Fnchigami LH. (1989). The role of phenolic compounds in plant stress responses; Low temperature stress physiology in crops (Paul H.L., ed.), *CRC Press Inc*., Boca Raton, Florida, 40.

Dixon RA, Paiva N. (1995). Stressed induced phenyl propanoid metabolism. *Plant Cell* 7:1085–1097.

Navarro JM, Flores P, Garrido C, Martinez V. (2006). Changes in the contents of antioxidant compounds in pepper fruits at ripening stages, as affected by salinity. *Food Chem*., 96: 66–719.

Petrusa LM, Winicov I. (1997). Proline status in salt tolerant and salt sensitive alfalfa cell lines and plants in response to NaCl. *Plant Physiol Biochem.* 35:303–10.