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Variations in production of bioactive compounds under abiotic stresses in the plants: A review

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Abstract

Plants are surrounded by complex set of environmental conditions which are categories into abiotic and biotic factors. The growth, development and overall survival of plants are regulated by the intensity of stresses exerts by biotic and abiotic factors of the environment. Stresses act individually or co-occurrence of different stresses at a time on plants and its study is challenging and complex process. However, the response of plants to the stresses is equally complex. Plant produces bioactive compounds in response of stresses as a stress tolerance. These bioactive compounds are also called secondary metabolites which plays significant role in the adaptation of plants to the stress condition and changing environment.In the present chapter emphasis was given on the study of production of different bioactive compounds in response to different abiotic stresses. The subtitles, types of bioactive compounds studied in plants showed wide variety of bioactive compound produce by plants in response to stress. Plant encounter number of abiotic stresses in plants like cold, heat drought, salinity, temperature and flood etc. Another subtitle, the impacts of different abiotic stresses on production of bioactive compounds in plants showed, the species of the families like Asteraceae, Papvaraceae, Apocynaceae, Lamiaceae, Brassicaceae, Malvaceaeetc shows responses to abiotic stresses and effect of abiotic stresses on productivity of agricultural crop plants. Overall study concluded that in this technological era several changes in environmental condition exert tremendous pressure of abiotic stresses on plants especially interfering with the productivity of agricultural land plants. Review shows that many plants cope up with the abiotic stresses by synthesizing bioactive compounds as a stress tolerance, but some plants fail to acclimatize and eventually die.

Keywords: Stress biology; Secondary metabolites; Abiotic stress; Medicinal Plant; Terpenes

1. Introduction

Plants are the main constituents of the biosphere which potentially contribute for serving life on the earth. Various natural resources are derived only from the plant sources. Plant produce primary metabolites for their normal growth and development while Secondary metabolites such as alkaloids, terpenes, flavonoids, lignans, plant steroids, curcumines, saponins, phenolics and glucosides (Hahn, 1998; Ramawat *et. al*., 2009) are organic molecules that are not involved in the normal growth and development of an organism but act as a part of their active defense system. Medicinal plants function as a storehouse of secondary metabolites and evolved to produce a wide spectrum of

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secondary metabolites in response to some kind of stress (Punetha, 2022). Secondary metabolites differ from one plant to another and one species to another and generally their level rise during the period of high stress (Taiz and Zeiger, 2006).The production of secondary metabolites in plant helps human being for emerging the field of Ayurveda where secondary metabolites are used as a medicine to treat animal diseases. This practice of using plant part as a medicine was very ancient so it is called as herbal medicinal system & traditional medicine system. The World Health Organization states that 80% of the world population relies on traditional medicine that is derived mainly from plants. Moreover 30% of conventional drugs are of natural origin (WHO, 1999). The natural products which contain a curative capacity use for the treatment of major and minor human disease (Verma and Singh, 2008). The amount of production of these natural products in plants depends upon different environmental condition and factors.

Environmental factor which is potentially unfavorable for the growth and development of plant is called as stress. According to Lichtenthaler (1996), environmental factors that affect the growth as well as biochemical expression of plants are termed as stress (Lichtenthaler, 1996). There are mainly two types of Stresses Biotic and Abiotic stresses which affect the growth and development of plant in large scale. Biotic stresses include effect of living organisms e.g., fungi, insects, viruses, bacteria, herbivores, weeds etc. (Mittler, 2006). Abiotic stresses are environmental and non-biological in nature e.g., climate [rainfall (e.g., annual rainfall and distribution; floods/drought), temperature (heat, cold, chilling), light (day length, shade, high light intensity)] and soil conditions [i.e., physical properties (particle size, water holding capacity), chemical nature (pH, salinity, organic and inorganic nutrients (fertilizers). Various kinds of abiotic stresses are prospective harmful to the plants like temperature, salinity, drought, flood, radiation, chemical as well as mechanical stresses which affect the concentration of various secondary plant products and reduces the yield of the crops (Tuteja, 2007). Abiotic stress gives a deleterious effect on plants by drastically alter the metabolic activity of the cell by producing the excess quantity of reactive oxygen species (ROS) in plant. In plants, ROS play a dual role such as toxic nature as well as work as key regulators for many biological processes like growth, programmed cell death, cell cycle, hormone signalling and cell responses and development (Miller, 2008).

Abiotic stress promotes production and accumulation of secondary metabolites in plant cells. Multiple stresses imposed by abiotic factors leads to stimulation of membrane bound receptors which initiates a cascade of signaling for biosynthesis of secondary metabolites. The secondary metabolites enable the plant species to cope up with adverse effect of abiotic as well as biotic stress. Depending upon the type of abiotic stress the endogenous level and type of secondary metabolite can be varying even in similar plant species (Radusience *et al.,* 2012). For instance, abiotic factor such as nutrient deficiency, UV radiation, wounds salinity, draught, circadian rhythm, temperature, flood, and metal ions can influence endogenous level of secondary metabolites (Verma and Shukla, 2015). Apart from this, secondary metabolite biosynthesis during abiotic stress also varies with metabolic pathways, growth condition, genetic factors and factors affecting expression of genes mediating secondary metabolite biosynthesis (Kliebenstein, 2013). The variation in synthesis of secondary metabolites with type of abiotic stress has been discussed in detail.

2. Types of naturally occurring bioactive compounds in plants

The compound naturally synthesized by plant parts and has active biological activity and applications in healthcare are called bioactive compounds. Bioactive compounds are extra-nutritional constituents that are found in small quantities in foods such as fruits, vegetables, nuts, and oils providing health benefits beyond the basic nutritional value of the product. Many of these bioactive compounds are beneficial for human health and have been studied extensively in the past. These compounds can then be defined as plant secondary metabolites eliciting pharmacological or toxicological effects in humans and animals (Bernhoft, 2008). These secondary metabolites are an extremely diverse group of natural products synthesized by plants.

Many studies showed that the synthesis of bioactive compounds is directly proportional to the exposer of stresses in plants.Plants undergo several physiological and biochemical changes under stress and show variable expression of the bioactive compounds under stress conditions (Nouman, et al., 2018). Biologically active metabolites perform a significant role in plants' adaptation, and they are responsible of plant protection from different biotic or abiotic stress factors (Ramkumar Samynathan et al., 2021). The photosynthetic pigment concentration, the flavonoid content, and total phenolic content decrease for all stressed plants and directly impacts basil plants' physiological parameters and secondary metabolites (Copolovici, Lucian et al., 2021).

Based on their biosynthetic origin secondary metabolites are categorized into three main classes these includes terpenes, phenolics (flavonoids and phenylpropanoids), and nitrogen containing compounds (alkaloids, cyanogenic glycosides and glucosinolates).

2.1. Terpenes

Terpenes are derived from five carbon units generally known as isoprene. Based on the fusion of repetitive number of isoprene unit terpenes are classified as hemiterpenes (one isoprene unit), monoterpene (two isoprene units), sesquiterpene (three isoprene units), diterpene (four isoprene units) triterpene (five isoprene units), tetraterpene (six isoprene units) and polyterpenoid with more than seven isoprene units. Various types of abiotic stresses stimulate synthesis and accumulation of terpene (table 1).

Table 1 Types of terpenes synthesised during abiotic stress in various plants

Class	**Terpenes**	**Source Species**	**Produced in response to**	**References**
Monoterpene	Volatile organic compounds	Grapevine (*Vitis* L.)	Photoinhibition of photosynthesis	Bertamini *et. al.,* 2019
	α-pinene, β-pinene, β-citronellol, camphene and 3-carene	*Pseudotsuga menziesii* (Mirbel.) Franco	Salinity and Draught Stress	Kleiber *et. al.*, 2017
Diterpene	Carnosic acid	*Salvia fruticose* Mill., *S. Officinalis* L., *Rosmarinus officinalis* Spenn.	Salinity and Draught Stress	Munne-Bosch and Alegre, 2003
Sesquiterpene	ABA, zeaxanthin	*Zea mays* L.	Salinity and Draught Stress	Vaughan *et. al.,* 2015
	(E)-α-Bergamotene, (E)-β-Farnesene	*Nicotiana attenuate* Torr. ex S. Watson	Tropospheric ozone	Palmer-Young *et. al.,* 2015
Triterpene	Saponin (QB 90)	*Quillajabra siliensis* L.	Radiation (UV)	De Costa *et al.*, 2013
Tetraterpene	Astaxanthin, β carotene	*Schizochytrium sp.*	Freezing, Metal ion	Li *et al.,* 2022

2.2. Phenolic Compounds

These are essential secondary metabolites which contain phenyl ring with hydroxyl group(s) in their structure. Phenolics are heterogenous molecule having aqueous and organic solvent solubility (Ali *et al*., 2013). In plants, biosynthesis of phenolic compound takes place through both shikimic and malonic acid pathways whereas in microorganism it involves only malonic acid pathway (Cheynier *et al*., 2013 and Swieca *et al*., 2014).A wide range of compounds constitutes phenolics which can occur in either free form or conjugated form with sugar, acids or other biomolecules (Fang *et al*., 2011). phenolic compounds categories are shown in figure.

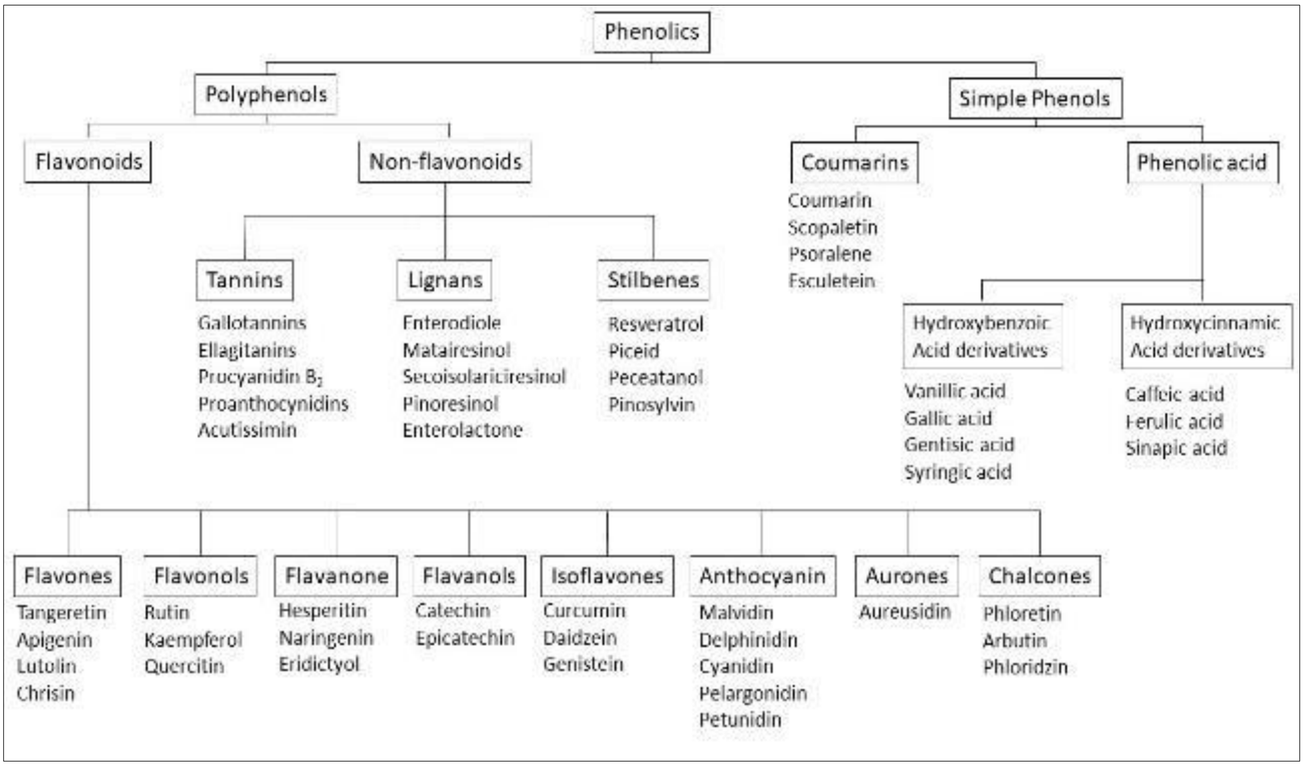

Figure 1 Classification of phenolic compounds

2.3. Nitrogen Containing Compounds

Alkaloids, glucosinolates and cyanogenic glycosides are important nitrogen containing secondary metabolites. Amino acids tyrosine, tryptophan, and lysine acts as precursor for synthesis of alkaloids (Khalil, 2017). Glucosinolates are also derived from amino acid. Based on the type of precursor amino acid glucosinolates are categorized as indolic glucosinolates (Trp acts as precursor) aliphatic glucosinolates (Ala, Ile, Leu, Met, Val acts as precursor), aromatic glucosinolates (Phe or Tyr acts as precursor) (Sonderby*et al.*, 2010). The cyanogenic glycosides are unique class of secondary metabolite which possess nitrile moiety in their structure. In higher plants synthesis of cyanogenic glycosides are closely related to the biosynthesis of glucosinolates. Classification of nitrogen containing secondary metabolites are shown in table 2.

Table 2 Classification of nitrogen containing compound secondary metabolite based on their chemical structure with source species

Nitrogen Containing Compounds	Class	Example	Source species
Alkaloids	Pyridines	Ricinine	*Ricinus communis* L.
		Trigenelline	*Trigenella foenumgraecum* L.
		Arecoline	*Areca catechu* L.
	Pyrrolidines	Hygrine	*Erythroxylon coca* Lam.
		Stachydrine	*Stachys tubifera* L.
	Tropanes	Atropine	*Atropa belladonna* L.
		Hyoscyamine	*Atropa belladonna* L.
		Cocaine	*Erythroxylon coca* Lam.
	Pyrrolizidines	Senneciphylline	*Senecio platyphllus L.*

		Sennecionine	*Senecio vulgaris* L.
	Indoles	Reserpine	*Rouvolfia serpentine* (L.) Benth. Ex Kruz
		Vinblastine	*Catheranthus roseus* (L.) G. Don
		Physostigmine	*Physostigma venenosum* Balf.
		Strychnine	*Strychnos nux-vomica* L.
		Ergometrine	*Clavicepes purpurea* (Fr.) Tul.
		Erotamine	*Clavicepes purpurea* (Fr.) Tul.
	Isoquinolines	Corydaline	*Corydalis aurea* Willd.
		Papaverine	*Papaver somniferum* L.
		Emetine	*Uragoga ipecacuanha* (Brot.) L. Andersson
		Tubocurarine	*Chondodendron tomentosum* Ruiz & Pav.
		Berberine	*Hydrastis Canadensis* L.
	Quinolins	Quinidine	*Cinchona officinalis* L.
		Quinine	*C. officinalis* L.
		Cusparerine	*Cusparia trifoliate* Roxb.
	Imidazole	Pilocarpine	*Pilocarpus jaborandi* Holmes
	Steroid	Solanidine	*Solanum sp.* L.
		Funtumine	*Funtumia latifolia* L.
		Veratramine	*Veratrum viride* Aiton
		Connesine	*Holarrhena antidysentrica* (L.) Wall. ex A. DC
Glucosinolates	Indole glucosinolates	Glucobrassicin	*Brassica sp.*
	Aliphatic glucosinolates	Sinigrin	*Brassica sp.*
		Dehydroerucin	*Brassica sp.*
		Glucorapanin	*Brassica sp.*
	Aromatic glucosinolates	Gluconasturtiin	*Brassica sp.*
Cyanogenic glycosides	Aliphatic	Linamarin	*Manihot esculenta* Crantz
		Linustatin	*Hevea pauciflora* (Spruce ex Benth.) Mul. Arg.
		Heterodendrine	*Acacia crassiuscula* J. C. Wendl.
		Cardiospermin	*Cardiospermum grandiflorum* Sw.
		Volkenin	*Passiflora foetida* L.
		Passicoccin	*Passiflora coccinea* L.
		Tetraphyllin	*Turnera diffusa* Willd. ex Schult.
	Aromatic	Prunasin	*Prunus sp.*
		Amygdalin	*Rosaceae sp.*
		Taxiphyllin	*Girgensohnia oppositiflora* (Pall.) Fenzl
		Lucumin	*Calocarpum sapota* L.
		Xeranthin	*Xeranthemum cylindraceum* L.

3. Types of abiotic stresses

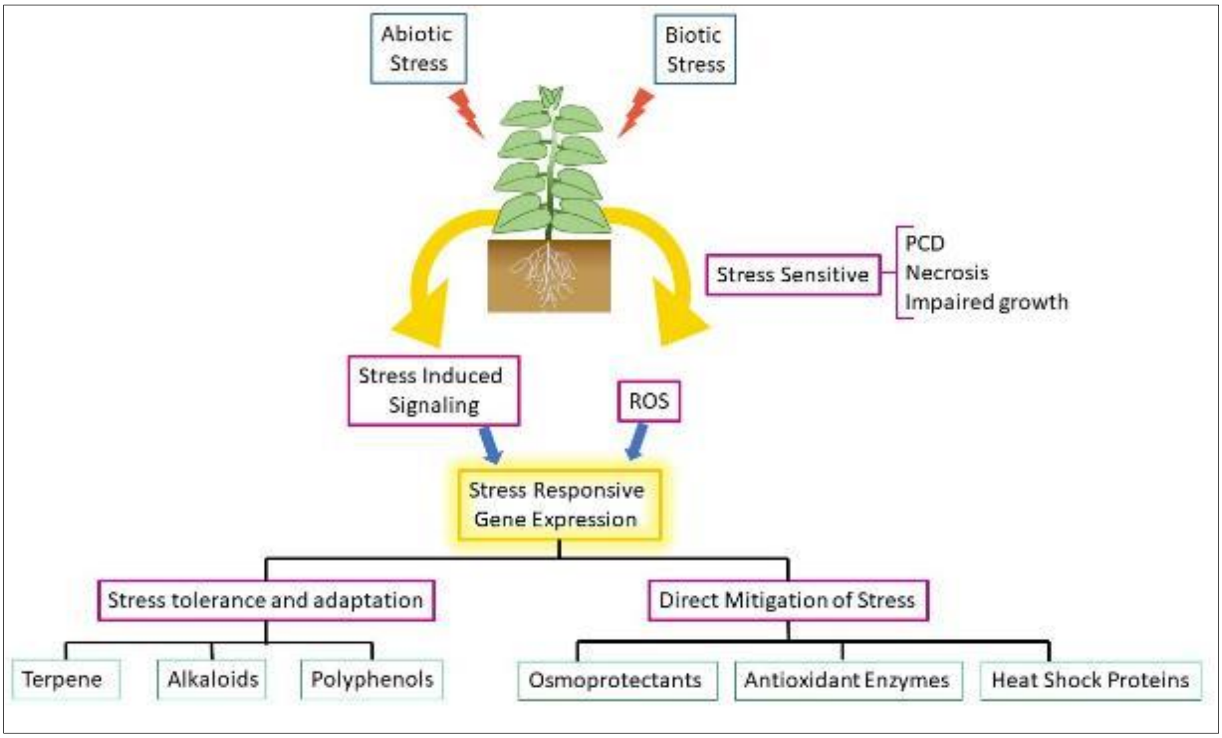

Figure 2 Schematic representation of stress and its mitigation

Stress caused by the inanimate components of the environment associated with climatic, edaphic, and physiographical factors that substantially limit plant growth and survival. Categorically these are abiotic stresses, which include drought, salinity, non-optimal temperatures. The challenges of abiotic stress on plant growth and development are evident among the emerging ecological impacts of climate change (Bellard et al., 2012). All abiotic stress impact plants life in a low or more intensity is shown in figure 2.

3.1. Temperature

- **Low/Freezing/frost injury:** Stress caused by sub-zero temperature i.e., 0°C or 0 to-10°C when most of the actively grown plants get killed or injured Chilling injury: Stress caused by low temperature i.e., 10 to 15°C or less but more than 0°C that cause injury mostly in warm season crops i.e., rice, maize, sorghum etc.
- **High:** Temperature is one of the important factors in the maintenance of cellular metabolism and its rise above optimum levels is perceived as heat stress by plants.Heat stress as an increase in temperature beyond a certain level for a period sufficient to cause irreparable damage to plant health (Wahid *et al*., 2007). Stress caused by temperature more than threshold that can be tolerated by plant i.e., mostly more than 40°C. When high temperature crosses thermal death point, it leads to death of the plants.

3.2. Water

Availability of water to the plants depends on the periodicity, degree of rainfall, sub-soil water status, water slope etc. Water stress may occur either due to water shortage or water deficit or due to excess of water. Physiologically, shortage of water in the soil is explained as the reduction in leaf water potential which occurs due to excess transpiration than the water absorption. That is, when water absorption lag behind transpiration, water deficit develops. It is also defined as, deficiency or dearth of water severe enough to check the plant growth.

- Deficit /Draught: It is the stress caused by combination of physical factors reducing water (low moisture stress) availability to the plant sufficient to retard the growth and development. When soil water depleted partially (or) totally (due to low precipitation). While the evaporative demand is high, along term imbalance is produced between water demand and supply. Drought is usually accompanied by high irradiance and temperature.
- Excess/Flood: It is the stress caused by excess moisture in the root zone that retard gas exchange (mainly O2) between soil environment and plant root causing hypoxic condition. A major constraint resulting from excess

water, at least for poorly adapted species, is an inadequate supply of oxygen to submerged tissues; diffusion of oxygen through water is 104-fold slower than in air (Armstrong and Drew, 2002). Flooding is a compound stress composed of interacting changes inside plant cells induced by the flood water surrounding the plant. The concentrations of oxygen (O2), CO2, reactive oxygen species (ROS) and ethylene change upon flooding and can occur in various combinations, as determined by the flooding regime (Perata et al., 2011).

3.3. Radiation

Stress caused by electro-magnetic radiation i.e. UV radiation causing mutation or degradation of biomolecules or IR radiation causing heat injury in plants. Being exposed to sunlight, plants need to deal with the damaging effect of ultraviolet (UV) radiation which reduces genome stability, impeding their growth and productivity. These effects result from damage to cell components including not only nucleic acids, but also proteins and membrane lipids. Upon UV exposure, strongly mutagenic cross-linked forms of DNA can be produced (Britt, 1999). UV-B radiation tolerance in plants is due to activation of UVR8 signaling which is related with expression of genes to protect the plant from photoinhibition and oxidative damage through synthesis of flavonoids, terpenes, and other secondary metabolites (Binkert *et al.,* 2014 and Jaiswal *et al.,* 2021). Gamma irradiation in plants have been reported multifold increase in phenolic compound in *Capsicum annum, Stevia rebaudiana, Panax ginseng* alkaloids in *Nathapodytes foetida* similarly flavonoids synthesis also increases in *Stevia rebaudiana* (Vardhan *et al.,* 2017).

3.4. Chemical

- Salinity stress: Stress caused due to excess soluble salt accumulation in root zone causingspecific ion effect or disturbance in mineral nutrient uptake or increasing osmotic potential. Salinity stress is caused by the accumulation of salts in the soil, which can lead to reduced plant growth and yield. Plants have developed several mechanisms to cope with salinity stress, including the synthesis of osmolytes, the compartmentalization of salts in vacuoles, and the regulation of ion transport across cell membranes. These mechanisms help plants maintain cellular ion homeostasis, enabling them to survive in saline environments.In Plantago ovata it was observed that increased synthesis of saponins and flavonoids seems to protect the plant from ion-induced oxidative stress (Haghighi et al., 2012). In Carthamus tinctorius salinity stress in known to increase flavonoid production in their leaves (Gengmao et al., 2015). The halotolerant plant growth promoting Rhizobacteria are known to provide salinity stress resilience to the plant by modulating SOS1 gene of the plant and production of secondary metabolites such as osmoprotectants, VOCs and exopolysaccharides (Morris et al., 2009 and Sunita et al., 2020).

3.5. Wind

Wind acts as an important abiotic factor for stress in many plant species. Wind in association with high temperature is known to influence the rate of transpiration. Among other mechanical stimuli such as touch, rainfall and physical obstacles, wind may interfere with growth and development in plants (Puijalon *et al*., 2011). Response to stress created by wind may differ in various parts of the plants and among members of the same species. Leaves are the most affected organ because wind may interfere with some physiological functions such as transpiration and photosynthesis (Huang *et al*., 2016). To cope with wind stress and other mechanical stress many plants species are reported to change lignin content and composition (Moura *et al*., 2010).

4. Impacts of different abiotic stresses on production of bioactive compounds

Review of literature showed that environmental factors have an impact on the plant growth and biosynthesis of secondary metabolites. Plants produce secondary metabolites to cope or adapt with any change or stress. Secondary metabolite production is often enhanced under stress (Hurmat et al., 2020). Since secondary metabolites are produced in response to stress, if one understands which environmental factor triggers the production of bioactive constituents, that particular factor can be altered during cultivation. Production of Bioactive compound in particular abiotic stress is shown below.

Water availability and unavailability impact significantly on bioactive compounds synthesis in plants. Water deficits of 38- and 62-hours increased leaf artemisinin content in Artemisia annua L. of family Asteraceae due to drought (Marchese et al., 2010). Increase in epicatechin content and Increase in Caffeine level in *Camelia sinesis* L. of Theaceae due to drought (Mello et al., 2006 and Munivenkatappa et al., 2018). Catharanthus roseus L. of Apocynaceae family showed increase in ajmalicine content (Jaleel et al., 2008). Water deficit increased percentage of petroselinic, oleic and palmitic acids in Coriandrum sativum L. of Apiaceae family (Yeganehpoor et. al., 2017). Echinacea purpurea L. of Asteraceae family showed increase in total phenol content due to drought (Gray et al., 2003). Increase in Morphine alkaloids in Papaver somniferum of family Papaveraceae due to drought (Szabo et al., 2008). Total biomass, leaf area, root mass increased and total phenolic glycosides increased in leaves by water deficit in Populus nigra or Black poplar of Salicaceae family (Hale et al., 2005). Prunella vulgaris L. of Labiatae family, drought stress with application enhances the production of rosmarinic acid, ursolic acid and oleanolic acid (Chen et al., 2011).

Increase in salinity is directly proportional to the tannin and alkaloid content in *Achillea fragratissima* L. of the family Asteraceae (Abd et al., 2009). Activity of antioxidant enzymes i.e. Glutathione reductase, Ascorbate peroxidase was stimulated with NaCl treatment in *Beta vulgaris* L. of the family Amaranthaceae (Bor et al., 2003). Polyphenols content of the halophytes increases in *Cakile maritima* of the family Brassicaceae due to increase in salinity (Ksouri et al., 2007). In *Cucumis sativus* L. of Apiaceae family, NaCl+ Silicon treatment significantly increased the dry weight of shoots and roots (Zhu et al., 2004). *Gossypium hirsutum* of family Malvaceae occur enductive response on antioxidant enzyme by salt stress (Meloni et al., 2003). Increase in content of Flavonoids in *Hordeum vulgare* L. of family Poaceae (Gulzar et al., 2003). In *Lycopersicon esculentum* of Solanaceae family increase in Sorbitol content due to salinity (Shivajirao, 2010). In *Mentha pulegium* L. of Labiatae family increase of total polyphenol content in leaves because of increase in salinity. Inductive response on antioxidant enzyme by salt stress in *Oryza sativa* L. of family Gramineae (Lee et al., 2001). In *Pisum sativum* L. of Leguminosae shows short term effect on antioxidant system due to salinity (Hernandeza and Almansa, 2002). Increase in thujone and camphor content in *Salvia officinalis* L. of family Lamiaceae due to salinity (Hendawy and Khalid, 2005). Salt stress decreases the level of carotenoids in plants but in combination of potassium fertilizer and salt stress the plant yield and level of carotenoids increased in *Simmondsia chinensis* L. of Simmondsiaceae (Hussein et al., 2014). Salt stress increased the contents of hydrogen peroxide (H2O2) and thiobarbituric acid reactive substances in *Triticum aestivum* L. of Gramineae family (Sairam and Srivastava, 2002). Salt stress effect the activity of superoxide dismutase in *Ulmus pumila* L. of family Ulmaceae (Song et al., 2006).

Concentrations of total flavonoid and phenolic compounds showed their highest values when quantitatively analyze the relationships between secondary metabolites and UV-B light interception (Hyo In Yoon, 2021). Flooding stress may increase stomatal resistance and limit water uptake, leading to an internal water deficiency (Isabel et al 2018).

5. Effect of abiotic stresses on productivity of agricultural crop plants

In the early 80s, estimated that environmental factors may reduce crop production by as much as 70% (Boyer, 1982). Since then, several reports have been published mentioning crop loss due to various abiotic stresses. Some of these stresses cause irreversible effects to cultivated lands and ultimately affect crop production and quality. Climate change is predicted to affect agricultural production the most, primarily at low latitudes populated by developing countries, with adverse effects of increasing carbon dioxide and high temperature, challenging researchers toward devising adaptation strategies (Rosenzweig et al., 2014). These constraints to global food supply and a balanced environment encourage research and development of climate smart crops, resilient to climate change (Wheeler and Von Braun, 2013). Although it is difficult to estimate the effects of abiotic stresses on agricultural lands (Wu et al., 2007 and Deng, 2005).

In today‘s climate change scenarios, crops are exposed more frequently to episodes of abiotic stresses such as drought, salinity, elevated temperature, submergence and nutrient deficiencies. These stresses limit crop production. Both biotic (e.g., phytopathogens) and abiotic stresses (e.g., drought, salinity, flood, storm, and extreme temperatures) cause enormous losses in agricultural production (Fraire-Velazquez and Balderas-Hernandez, 2013). Abiotic stresses, such as drought, salinity, extreme temperatures, chemical toxicity and oxidative stress are serious threats to agriculture and the natural status of the environment. Plant growth, development, productivity, and resistance to climatic stresses are currently the major topics of interest for agriculture and plant-based biotechnologies. Increased salinization of arable land is expected to have devastating global effects, resulting in 30% land loss within the next 25 years, and up to 50% by the year 2050. Therefore, breeding for drought and salinity stress tolerance in crop plants (for food supply) and in forest trees (a central component of the global ecosystem) should be given high research priority in plant biotechnology programs (Wang et al., 2003).

The field of plant abiotic stress encompasses all studies on abiotic factors or stressors from the environment that can impose stress on a variety of species (Sulmon et al., 2015). These stressors include extreme levels of light (high and low), radiation (UV-B and UV-A), temperature [high and low (chilling, freezing)], water (drought, flooding, and submergence), chemical factors (heavy metals and pH), salinity due to excessive Na+, deficient or in excess of essential nutrients, gaseous pollutants (ozone, sulphur dioxide), mechanical factors, and other less frequently occurring stressors. Since combinations of these stresses such as heat and drought frequently occur under field conditions, and can cause unique effects that cannot be predicted from individual stressors (Suzuki et al., 2014).

Agricultural plants showed symptoms in response to different stress like flowering in rice are extremely sensitive to low temperatures and damage may occur at temperatures as low as 20°C show Wilting of leaves, bleaching due to photo-oxidation of pigments, Water logging of the intercellular spaces, Browning Leaf necrosis and plant death. On other hand due to water stress very frequent even in well irrigated plants whenever evaporative demand is higher than the xylem capacity for refilling leaves.

In recent years, advances in physiology, molecular biology and genetics have greatly improved our understanding of crops response to these stresses and the basis of varietal differences in tolerance

6. Conclusion

In the environment, plants are constantly being exposed to several adverse conditions. Being immobile and deprived of highly specialized immune system, they have developed intricate mechanisms to adapt and survive under various types of abiotic stresses. On the perception of certain stimuli various signaling cascades are stimulated generating appropriate responses. This result in massive transcriptional reprogramming that makes the plant tolerant against the stress. Bioactive compound production in plants is dependent upon the intensity of stress and response of plants toward this stress.Response toward stress is the tolerance of the plant. Above study concluded that plant produce secondary metabolites in response of abiotic stress this phenomenon open number of doors for the researchers to study in this field.

Compliance with ethical standards

Disclosure of conflict of interest

All authors have no conflict of interest including any financial, personal or other relationships with other people or organizations that can influence their work.

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