IJPS INTERNATIONAL JOURNAL OF PLANT SCIENCES
e ISSN-0976-593X Volume 12 | Issue 2 | July, 2017 | 309-313

DOI: 10.15740/HAS/IJPS/12.2/309-313
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REVIEW ARTICLE

Positive impact of abiotic stress on medicinal and aromatic plants

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SUMMARY

Abiotic stress is the imbalance in the environmental status that affects the normal growth, development and reproduction of an organism. Various abiotic stresses are drought, salinity, heat, flood, reactive oxygen species etc. Generally stress cause reduction in quality and quantity of yield in agricultural crops. But in case of medicinal and aromatic plant it has been found to enhance both qualitative and quantitative yield. In this article we are going to understand the mechanism that will change our view towards abiotic stresses.

Key Words : Abiotic stress, Medicinal plants, Quality yield, Advantage of stress

How to cite this article : Pradhan, J., Sahoo, S.K., Lalotra, S. and Sarma, R.S. (2017). Positive impact of abiotic stress on medicinal and aromatic plants. *Internat. J. Plant Sci.,* **12** (2): 309-313, **DOI: 10.15740/HAS/IJPS/12.2/309-313**.

Article chronicle : Received : 16.01.2017; **Accepted :** 27.06.2017

Plant secondary metabolites are often referred to as compounds that have no fundamental role in the maintenance of life processes such as growth, development and reproduction, but they play significant role for the plant to interact with its environment for adjustment, adaptation and defence. In higher plants a wide variety of secondary metabolites are synthesized from primary metabolites (e.g., carbohydrates, lipids and amino acids). They are needed in plant defense against herbivores and pathogens. Often they may grant protection in opposition to environmental stresses. Plant secondary metabolites are unique sources for food additives, flavors, aroma, medicines, cosmetic products and industrially important pharmaceuticals. The production of these compounds are generally low (less than 1% dry weight) and depends greatly on the physiological and developmental stage of the plant (Rao and Ravishankar, 1989). Various biotic and abiotic stresses have been found to increase the accumulation of phynylpropanoids (Dixon and Paiva, 1995) and phenolic compounds (Chalker-Scott and Fnchigami, 1989). The concentrations of various secondary plant products are strongly dependent on the growing conditions and physiology and are having impact on the metabolic pathways responsible for the accumulation of

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the related natural products. The expression level of certain genes governing the production of such compounds have been shown to increase in response to various abiotic stresses (Tuteja, 2007). In this review we have briefed the mechanisms happening with each abiotic stress.

Drought :

Drought stress is one of the most significant abiotic stress that affect plant growth and development (Xu *et al*., 2010). It occurs when the available water in the soil is reduced to such critical levels and atmospheric conditions adds to continuous loss of water. Drought cause huge damage to the physiological machinery of the plants resulting in degradation of morphological topology (*i.e.* plant height, leaf number, leaf area, number of tillers, number of branch, number of root nodules, root volume, panicle length, number of flowers etc.), anatomical structure (*i.e.* stomata number, chlorophyll content, pollen size etc.) and biochemical activity (*i.e.* enzyme activity, protein content, sugar content etc.). There is increase in secondary metabolites such as saponin, anthocyanin and flavonoids in low water availability condition. In case of *Papaver somniferum* there is elevation in morphin content (Wang *et al.*, 2010) and in *Scrophularia ningpoensis* high level of glucocides content (Szabo *et al.*, 2003) has been found in water deficit condition as compared to normal condition of growth. Drought stress cause abnormality in photosynthesis and transpiration that may affect the yield and composition of essential oil (EO). It was suggested that the reduction in leaf area due to water stress might result in higher density of the leaf oil glands, leading to an elevated amount of oil accumulation (Simon *et al*., 1992). According to Sangwan *et al*. (1993 and 1994) in case of *Cymbopogons* there was unlike changes in morphological parameters, but the oil content was increased. The activity of enzyme geraniol dehydrogenase was also modulated under moisture stress. Compositional alteration in EO content, occurring due to water stress, have also been elucidated in mint (Chattopadhyay and Subramanyam, 1993) and sweet basil (Simon *et al*.,1992). Such studies are giving an idea to layout a closer planting of medicinal and aromatic plants in drought affected areas might be a way of maintaining secondary metabolite production. Drought stress in different stages of plant growth also affect the EO contents. The accumulation of EO in Iranian *Satureja hortensis* L. increased significantly under severe water stress at the flowering stage (Baher *et al.*, 2002). Abbaszadeh *et al*. (2009) suggested amount of water deficit stress (*i.e.* moderate or severe) affect the oil content in balm (*Melissa officinalis* L.)

Salinity :

Salt stress limits agricultural production throughout the world and is becoming an increasingly global problem that affects approximately 20 per cent of global irrigated land. Salt environment lead to cellular dehydration, which causes osmotic stress and exosmosis of cytoplasm resulting in a reduction of the cytosolic and vacuolar volumes. Salt stress often creates both ionic as well as osmotic stress in plants, resulting in accumulation or decrease of specific secondary metabolites in plants. Osmotic stress created by sucrose and other osmatic agents was found to regulate anthocyanin production in *Vitis vinifera* cultures (Tuteja and Mahajan, 2007). Plant polyamines have been shown to be involved in plant response to salinity. In case of *Datura innoxia*, in saline situation the total content of tropane alkaloid has been found to be increased (Brachet and Cosson, 1986). Also in *Hordeum vulgare* the flavonoid content was found to be elevated (Ali and Abbas, 2003). Salinity stress generates oxidative stress in plant tissues (Abel *et al*., 2003), which is manifested by ROS (reactive oxygen species) such as singlet oxygen, superoxide anion, hydrogen peroxide, and hydroxyl radicals (Gosset *et al.*, 1994). Plants have evolved various protective mechanisms to eliminate or reduce ROS (Zhu, 2003 and Mittler *et al*., 2004). Free radical reactions, in participation with oxidative radicals, have been shown to be involved in many biological reactions, causing damage to lipids, proteins, membranes, and nucleic acids, thus giving rise to a variety of metabolic disorders (Cavalcanti *et al .*, 2006). Plant stress responses involve the synthesis of several secondary metabolites of phenylpropanoid pathway to defend the plant metabolism. Phenolic compoundsare intermediates in the phenylpropanoid pathway and play important roles in flavonoid production and lignin biosynthesis (Zheng *et al.*, 2001). In fact, it has been determined that the antioxidant effect of plant products is mainly due to phenolic compounds, such as flavonoids, phenolic acids, tannins and phenolic diterpenes (Lee *et al.*, 2004). Phenolic compounds play an important role in adsorbing and neutralizing free radicals, quenching singlet oxygen, or decomposing peroxide radical (Ksouri *et al.*, 2007).

Heavy metal :

Heavy metal pollution is an increasing problem in agricultural soils. Heavy metals are found naturally in the soils as rare elements and also added to the environment due to heavy traffic, refuse dumping, and metal working industries. Heavy metal stress is having several undesirable effects on plants leading to plant death and human health hazards. The most abundant heavy metals are lead (Pb), aluminium (Al), cadmium (Cd) etc. The Pb toxicity leads to inhibition of enzyme activities, disturbed mineral nutrition, water imbalance, change in hormonal status, and membrane permeability (Sharma and Dubey, 2005). In most of the cases, Pb interacts with free -SH groups that are present in the active site of the enzyme. One of the most prominent effects of Al toxicity on plants is inhibition of cell elongation. According to Rengel (1992), interaction of Al^{3+} with the cell wall components could be responsible for the observed Al toxicity symptoms in plants. Ca^{2+} also plays a key role in cross-linking the pectic materials in the cell wall (Carpita and Gibeaut, 1993). Khaligh *et al.* (2007) registered an increase in melon di-aldehyde content along with the increase in the activities of detoxifying enzymes, guaiacol peroxidase, and ascorbate peroxidase, in wheat leaves grown under cadmium stress.

Light :

The parameters of light intensity, quantity and quality have been shown in other crops to be very important for uniformity and consistency in plant production (Albright *et al.*, 2000). It is well known that light is a physical factor which can affect the metabolite production. Light can stimulate such secondary metabolites include gingerol and zingiberene production in *Z. officinale* callus culture (Anasari and Asghari, 2008). American ginseng plants exposed to longer sunlight were found to have higher root ginsenoside contents than those exposed to shorter periods of direct sunlight (Li *et al.*, 1996). A positive correlation between increasing light intensity and levels of phenolics has been reported (Chalker-Scott and Fnchigami, 1989). UV light is a natural elicitor of secondary metabolite responses. Supplemental exposure to UV-B light has been shown to increase the concentration of secondary metabolites in maize, basil and peanut (Gao *et al*., 2004; Johnson *et al*., 1999 and Chung *et al.*, 2001). UV-B has been shown to be the stimulus for anti-feedent properties (Cassi-Lit, 2005). It has been reported maximal production of metabolites has been linked to the flowering stage of *Hypericum perforatum* plant (Thomas, 1948). This is giving a clear cut idea about the fact that also photoperiod is affecting the secondary metabolite content. In *Vanilla planifolia*, blue light has been found to increase the vanillin content (Havkin-Frenkel *et al*., 1996).

Temperature :

High and low temperature cause drastic change in physiological and biochemical processes, including water deficit and oxidative stress leading to lipid peroxidation and membrane damage, degradation of chlorophyll and protein, and reduced water status of plants (Suzuki and Mittler, 2006). Ali *et al.* (2005) reported that high temperature stress (at 25–40^0C) induced not only the activities of ROS scavenging enzymes, but also increased the activity of lipoxygenase and the content of melon di-aldehyde and cysteine as well as that of protein and non-protein-thiol in the leaf and root segments of *Phalaenopsis* . Lower temperature favors anthocyanin accumulation, but reduces cell growth. In case of straw berry maximum anthocyanin content was observed at 15^0C and this amount was 13 fold higher than the same obtained at 35^0C (Zhang *et al*., 1997). Cao *et al.* (2011) showed that low temperature inhibited the growth of oil palm seedlings. Whereas, relative conductivity, injury index, melon di-aldehyde, and proline content in the leaves were increased to different degrees with the extension of low temperature stress. Elevated temperatures increase leaf senescence and root secondary metabolite (*i.e.* ginsenoside) and reduce photosynthesis and biomass production concentrations in the herb *Panax quinquefolius* (Jochum *et al.*, 2007).

Green house gases :

From the ancient time it has been known that green house gases are responsible for the enhancement of medicinal value of the plants. It is well known about the fact that initially the CO_2 content was too high and during the process of evolution the medicinal plants are the one whose stability is for a broad range of environment. In mountains also, in the heights the UV and ozone gas level is high and there we can find very high quality medicinal plants and even those species which are about to extinct. Here are some findings regarding the green house gases. He *et al.* (1928) reported the effect of CO_2 or ozone on endogenous hormones in the leaves of *Ginkgo biloba*. Huang *et al*. (1929) reported that elevated O_3 reduce the concentrations of the isorhamnetin aglycon (7%), but increase the concentration of quercetin aglycon (6%). Elevated CO_2 reduce the concentrations of keampferol aglycon (10%), isorhamnetin aglycon (15%). Ozone exposure has been shown to increase conifer phenolic concentrations (Rosemann *et al*.,1991).

Conclusion :

Thus it is evident that abiotic stress is increasing the secondary metabolite production in the plants, which is elevating the phytomedicine production and also encouraging the yield of essential oil in aromatic plants. In this era of climate change this is an opportunity to the farming community to shift the cropping practices from the traditional crops towards the medicinal and aromatic crops in developing countries like India. The need of time is opening a path for organic and herbal products, which may grant advantage to advances in medical sciences as well as to the overall agricultural production and productivity. This will also add to the productivity of barren land and uplift the cultivation of under exploited crop. In brief it is an offer for us to take benefit of disastrous climate change.

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