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# Secondary Metabolite Production In Plants: In Response To Biotic And Abiotic Stress Factors

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***Abstract***

Secondary metabolites (SMs) play vital roles in plant defence mechanisms, adaptation to environmental conditions, and interactions with other organisms. Biotic and abiotic stress factors can significantly influence the production, accumulation, and composition of SMs in plants. Understanding the intricate relationship between stress and SM production is crucial for enhancing plant resilience, agricultural productivity, and the development of novel phytopharmaceuticals. This research provides current knowledge regarding the impact of biotic and also abiotic stress on SMs in plants. Biotic stress factors such as pathogen infection, and herbivore attacks, as well as abiotic stress factors like drought, along with temperature extremes, and also salinity, can profoundly influence the biosynthesis and accumulation of SMs in plants. We discussed the methodology based on secondary sources underlying physiological, biochemical, and molecular mechanisms involved in stress-induced SM synthesis and highlight the potential implications for plant biology, agriculture, and human health. The study also emphasizes the functions of SMs in plants including defence against herbivores, pathogens, and abiotic stresses. The mechanism by which these compounds act as allelochemicals and signalling molecules is also discussed.

***Keywords: SMs, Biotic stress, Abiotic stress, Plant defence, Stress response.***

## Introduction

Apart from being a helpful variety of natural products, plant SMs are a key part of a plant's defence system versus pathogenic attacks and environmental problems. Plant SMs are organic compounds synthesized by plants that indirectly take part in primary metabolic processes such as growth, development, and reproduction[1]. Plant SMs are being employed more frequently as food and pharmaceutical additives for medicinal, aromatic, and gastronomic purposes because of their amazing biological capabilities. Numerous genetic, along with ontogenic, as well as morphogenetic, and also environmental factors may affect SM biosynthesis and accumulation.

Biotic stress factors, such as pathogen attacks, herbivory, and competition from neighbouring plants, can significantly influence the SM production in plants. These stress factors trigger a cascade of defence responses within the plant, leading to changes in gene expression and metabolic pathways. As a result, the production of specific SMs may be upregulated or downregulated in reply to biotic stress. For example, during a pathogen attack, plants may increase the production of phytoalexins, which are antimicrobial SMs that help fend off the invading pathogen[2].

Similarly, abiotic stress factors like drought, salinity, temperature extremes, and nutrient deficiencies can also influence the SM production in plants. Plants respond to these stresses by activating a wide range of defence mechanisms, both physiological and biochemical. These mechanisms often involve the synthesis and accumulation of SMs that help plants tolerate or adapt to stressful environments. For instance, drought stress can stimulate the production of osmoprotectants such as proline and soluble sugars, which aid in maintaining cellular water balance and protecting cell structures from damage. Moreover, research has shown that the environmental factors surrounding plants of the same species can result in variations in SM concentrations[3].

This variation in SM production can have implications for the effectiveness of certain pharmacological activities that rely on the presence of specific bioactive compounds. Therefore, understanding the influence of biotic and also abiotic stress factors on SM production is crucial for various fields including pharmaceuticals, agriculture, and ecology. In the field of pharmaceuticals, this knowledge can help researchers identify optimal conditions for cultivating medicinal plants and maximize the production of bioactive compounds with therapeutic potential[4]. In the agricultural sector, understanding the influence of biotic and also abiotic stress factors on SM production can aid in developing strategies for crop management and enhancing the nutritional value and quality of agricultural products[5].

Furthermore, in ecological studies, the influence of biotic and also abiotic stress factors on SM production can provide insights into plant defence mechanisms and interactions with other organisms in their environment[6]. Additionally, the study of biotic and also abiotic stress factors on SM production can contribute to our comprehension of plant evolution and adaptation. Overall, the influence of biotic and also abiotic stress factors on SM production in plants is complex and multifaceted. It plays a crucial role in shaping plant physiology, biochemistry, and ecological interactions. This research paper highlights key examples from the literature to illustrate the diverse impacts of biotic and also abiotic stress factors on plants' SM production. A deeper understanding of the underlying mechanisms governing SM biosynthesis in stress conditions will pave the way for future research aimed at manipulating plant metabolism to enhance stress tolerance and improve the production of valuable bioactive compounds. The aim of the research is to understand the responsible mechanisms involved with plants' SM production under stress conditions. These studies help in the production of plant therapeutics, agricultural, and other metabolite production.

**Materials and Method:** To investigate the impact of biotic and also abiotic stress factors on plants' SM production, secondary data was collected from various scientific sources. The following steps were taken to gather relevant information.

**Literature survey:** A comprehensive search was conducted in electronic databases; PubMed, along with Google Scholar, and also Scopus, utilising keywords related to biotic and also abiotic stress factors, SMs, and plant responses. Relevant research articles, and review papers published during 2003-2023 were included in the data collection.

**Selection criteria:** The collected literature was screened based on the predefined inclusion and exclusion criteria. Only studies that focused on the influence of specific biotic and also abiotic stress factors on SM production in plants were included.

**Data extraction:** Relevant data, such as stress factors investigated, plant species, experimental design, and observed changes in SM production, were extracted from selected studies.

**Data synthesis and analysis:** The extracted data were synthesized to identify common patterns and trends regarding the impact of different stress factors on plants' SM production. Any discrepancies or conflicting findings were noted and further analysed to identify potential factors contributing to the variation.

**Quality assessment:** Included investigation's quality and reliability were evaluated utilising apt evaluation criteria, such as study design, sample type, and the reputation of the research journal.

**Ethical consideration:** As this study has relied on secondary data, ethical considerations were not directly applicable. However, in order to preserve credibility in the academic community, we made care to properly credit the works of the original writers.

The collected secondary data served as the foundation of the analysis and discussion of the influence of biotic and also abiotic stress factors on plants' SM production in the subsequent sections of this research paper.

## Results and Discussion:

### A. Effect of biotic stress factors on plants' SM production

Recent research has focused on examining the impacts of various biotic stress factors on plants' SM production. One prominent biotic stress factor that has been studied is the presence of pathogens and pests. Studies have shown that pathogen infestation can lead to the production of specific metabolites in plants, enhancing their ability to overcome biotic stress[7].

#### Pathogen infection

Another biotic stress fact that has been investigated is competition among plants. Research has shown that when plants are subjected to competition from neighbouring plants, it can affect the concentrations of certain SMs in the plants, potentially influencing their pharmacological activity[8].

#### Herbivore attack

Furthermore, the interaction between plants and herbivores has also been found to influence SM production. Herbivore feeding can induce the production of defensive SMs in plants as a response to biotic stress[9].

#### Symbiotic relationship

Additionally, studies have explored the influence of symbiotic interactions on SM production. Symbiotic relationships between plants and beneficial microorganisms, such as mycorrhizal fungi, have been shown to enhance SM production in plants[10]. These recent references highlight the diverse range of biotic stress factors that can affect plants' SM production. These studies emphasize the importance of understanding and managing biotic stress factors in order to optimize SM production in plants.

### B. Effect of abiotic stress factors on plants' SM production

#### Effects of drought

Studies have shown that under drought conditions, the synthesis of SMs in plants increases. For example, the content of morphine in *Papaver somniferum* and glucosides in *Gossypium hirsutum* were found to increase under water deficit conditions[11]. Furthermore, the accumulation of phenolic compounds, along with flavonoids, and anthocyanin in various plant species was observed to promote antioxidant capacities during drought conditions.

#### Impact of heavy metal stress

In reply to heavy metal stress, plants adopt different defence mechanisms and synthesize SMs to cope with the associated problems. For instance, the accumulation of anthocyanins in lettuce leaves was found to decline under nickel stress, while cumulative accumulation of chromium, iron, zinc, and manganese increased oil production in *Brassica juncea* plants[12]. Copper was also found to stimulate betalain production in *Beta vulgaris* plants. These SMs, along with endogenous enzymatic and non-enzymatic antioxidants, help plants scavenge free radicals and minimize oxidative stress.

**Effect of temperature stress**

Low temperatures induce the synthesis of cryoprotectant compounds; sugar alcohols, along with soluble sugars, and also low-molecular-weight nitrogenous compounds to protect plants from the adverse impacts of cold stress. Cold stresses have also been known to enhance the production of phenolic compounds. On the other hand, high temperatures can adversely affect the synthesis of SMs, such as carotenoids in *Brassicaceae* family plants. Studies have shown that the concentrations of quercetin and kaempferol in *Medicago sativa* plants were higher at warmer temperatures, while more putrescine content was observed under low-temperature environments[14].

**Influence of light**

Light exposure has been found to enhance the biosynthesis of SMs, including gingerol and also zingiberene within *Zingiber officinale* plants. UV-B exposure has also been shown to increase the content of flavonoids in barley and polyamines in cucumber. Furthermore, light has been found to enhance the biosynthesis of terpenoid indole alkaloids within *Catharanthus roseus* plants[15].

**Effects of salinity stress**

Studies have shown that secondary plant products, including proline, along with glycine betaine, carotenoids, total phenolic contents, and also total flavonoids, increase with increasing salinity levels in plants such as *Carthamus tinctorius* and *Lycopersicon esculentum*. These SMs help plants maintain their physiology and antioxidant capacities during salinity stress[16].

**Regulatory mechanisms**

The synthesis and accumulation of secondary plant metabolites in reply to biotic and also abiotic stress factors are regulated by intricate molecular mechanisms. The following are the key regulatory mechanisms identified in recent studies that shed light on this topic,

**Signalling pathways**

Biotic and abiotic factors often activate specific signalling pathways that play a crucial role in regulating SM production in plants[17].

1. The jasmonic acid (JA) pathway is linked with a defence response against insect, herbivory, and necrotrophic pathogens. It regulates the synthesis of various SMs including terpenoids, phenolics, and glucosinolates, which act as deterrents against herbivores and pathogens.
2. The ethylene (ET) pathway is involved in plant responses to pathogen attacks and adverse environmental conditions. It modulates the biosynthesis of SMs such as volatile organic compounds (VOCs), phytoalexins, and lignin, which contribute to defence and stress tolerance.
3. Plant resistance against biotrophic diseases relies heavily on the SA pathway. It regulates the SM production, including phenolics, flavonoids, and alkaloids, which possess antimicrobial properties.

**Transcription Factors**

Transcription factors (TFs) including WRKY, MYB, and AP2/ERF transcription factors mediate the response to biotic and abiotic stress factors, leading to altered SM production in plants[18].

**Epigenetic regulation**

Epigenetic modifications like DNA methylation, along with histone modifications, and also small RNA-mediated gene silencing, also contribute to the regulation of SM production under stress conditions. Recent studies have highlighted the importance of epigenetic regulation in modulating the expression of genes involved in secondary metabolism[19].

**Conclusion:**

In conclusion, the impact of biotic and also abiotic stress factors on plants' SM production is a complex phenomenon with significant implications. Biotic stress factors, such as pathogen infections, herbivory, and symbiotic relationship, as well as abiotic stress factors like temperature, salinity, drought, etc., profoundly influence the biosynthesis and accumulation of SMs in plants. These stressors trigger intricate signalling pathways, involving the action of transcription factors, and are subject to epigenetic regulation. Understanding the influence of stress on SM production has practical applications in agriculture, pharmaceuticals, and other industries. Further research is needed to uncover additional regulatory mechanisms and explore the potential for manipulating plant metabolism and SM production.

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