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Stress in plant and their benefits for the secondary compound accumulation: a review

Thang Thanh Tran[1,2*] & Van Hai Phan[3]

[1]Department of Plant Physiology, University of Sciences, Ho Chi Minh City 7000, Vietnam

[2]Vietnam National University, Ho Chi Minh City 7000, Vietnam

[3]Department of Plant Physiology and Biochemistry, Nong Lam University, Ho Chi Minh City 7000, Vietnam

*Email:trtthang@hcmus.edu.vn

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Abstract

In recent years, crops have often experienced an increasing number of abiotic and biotic stresses, which significantly impair their growth and output due to global warming and accompanying climatic irregularities. Many studies have been carried out to improve plants' stress tolerance, including using fertilizers, microbial interactions, plant growth regulator application, and other methods. However, stress's role in improving a plant's ability to create a variety of secondary compounds such as phenolic acid, flavonoids, and anthocyanins, some of which have been linked to antioxidant activity and positive impacts on health, has yet to be well investigated. This review aims to summarize the potential for stress concerning the use of secondary compound content in plants.

Keywords

accumulation; plant; secondary compound; stress

Introduction

Plant ecosystems are rapidly and significantly impacted by climate change (1). According to several research studies, climate change has hastened plant ecological responses regarding distribution, ecophysiology, and interactions with other species (2–5). Plants generate a variety of secondary compounds due to overcoming climate change-induced stress, which may be of interest to the pharmaceutical industry (1). Stressors trigger the creation of bioactive chemicals, such as phenylpropanoids, which accumulate substances with signaling or defense activities (4). The higher accumulation of secondary compounds under stress conditions suggests that plants impacted by climate change may contain unidentified new bioactive alkaloids and phenolics (2). In a controlled environment, stress factors may increase the level of bioactive compounds produced.

The various secondary compounds, including polyphenols, alkaloids, and terpenoids that plants create play a part in many biological functions, including stress tolerance to biotic and abiotic factors (6). For instance, in response to abiotic and biotic stress such as microbial assault, chemical treatment, wounding, dehydration, or salt stress, the level of anthocyanins, flavonols, flavones, and tocopherols dramatically rises (6, 7). Plants may get stressed by alterations in their environment. Research on plants, especially those related to agricultural production, has increasingly focused on how stress affects metabolism and performance (7). Most plants undergo various bio-physiological changes in response to drought or salt, which may lead to oxidative stress and influence plant development (5, 8).

Methodology

To conduct this study, we utilized search platforms including Google Scholar, Web of Science, and Scopus. These platforms were chosen due to their wide range of academic and scientific literature, spanning multiple fields such as plant biology and plant stress responses. Our search criteria were focused on identifying pertinent articles related to our topic of interest. We carefully selected search keywords to ensure they accurately captured the essence of the topic, including terms such as "plant stress," "secondary metabolites," "abiotic stress," "biotic stress," "phenolic compounds," and "terpenoids." Additionally, we limited our search to peer-reviewed journals published in recent years, specifically from 2020 to 2023.

Different secondary metabolites present in the plant

In plants, secondary compounds are classified into four main groups based on their biosynthetic pathways (Fig. 1). Phenolic compounds are derived from the shikimate and phenylpropanoid pathways. This group includes flavonoids, tannins, lignins, and phenolic acids (6). Terpenoids are derived from mevalonic acid or the 2-C-methyl-D-erythritol-4-phosphate pathway (6). Terpenoids include monoterpenes, sesquiterpenes, diterpenes, and triterpenes. Nitrogen-containing compounds include alkaloids, cyanogenic glycosides, glucosinolates, and non-protein amino acids (7). These compounds are derived from amino acids. Sulfur-containing compounds contain sulfur atoms in their chemical structures and are synthesized through the sulfate assimilation pathway (8).

Phenolics

Plants can have different biochemical and physiological responses to both abiotic and biotic stresses, such as changes in gene expression, changes in metabolic pathways, and the buildup of secondary metabolites like phenolic compounds (8). Phenolic compounds are a diverse group of secondary metabolites that plants produce in response to various stresses, including both abiotic and biotic stresses (2). Many studies have demonstrated that plants under drought stress build up higher levels of secondary metabolites. Almost all phenolics, from simple (chlorogenic acid and phenolic acid) to complex (flavonoids and anthocyanins), are known to exhibit such an increase. Several phenolic chemicals, including betulinic acid, have been shown to significantly increase in concentration in *H. brasiliense* C. under drought stress (9). Similarly, *Myrica rubra* L. shows higher chlorogenic acids and anthraquinones in its leaf under drought stress (10). These effects are observed when the plant is exposed to medium-intensity water stress. The generation of biomass and the concentration of natural products resulted in an increase of 10% in the overall content of phenolic compounds, although smaller, stressed plants were involved. In fish mint (*Houttuynia cordata* T.), the drought treatment for 7 days enhanced flavonoid content from 2.42 mg to 3.04 mg (11). Also, it was noted that stressed peas had a notable rise in the content of phenolics. The anthocyanin content was around 25% greater overall, while the pea biomass produced under drought stress was only about 1/3 of that of those grown under usual conditions (12). The amount of furoquinone in red sage (*Salvia miltiorrhiza* L.) significantly increased when subjected to drought stress (12).

Terpenes

Regarding terpenoids, many studies have demonstrated a drought-stress-related rise in terpene concentration (13). The significant rise in monoterpene concentration brought on by drought stress in sage (*Salvia officinalis* L.) outweighed the associated loss in biomass by a substantial margin (14). Compared to *Salvia officinalis* L. grown under well-watered conditions, plants under mild drought stress have a 33% greater concentration of monoterpenes (15). Catmint and lemon showed a minor rise in monoterpene concentration under drought conditions (16). In contrast, *M. officinalis* L., *N. cataria* L., and *S. officinalis* L. have shown a drop in terpenoids level (17). Many fragrant plants, including *C. martinii* R., *C.winterianus* J., *M.officinalis* L., and *O. basilicum* L., have been researched for stress impact on essential oils (16-18). The impact of water stress on the synthesis of lemongrass essential oils in *C. nardus* L. and *C. pendulus* W. (19) was studied. According to the experiment's findings, under drought-like

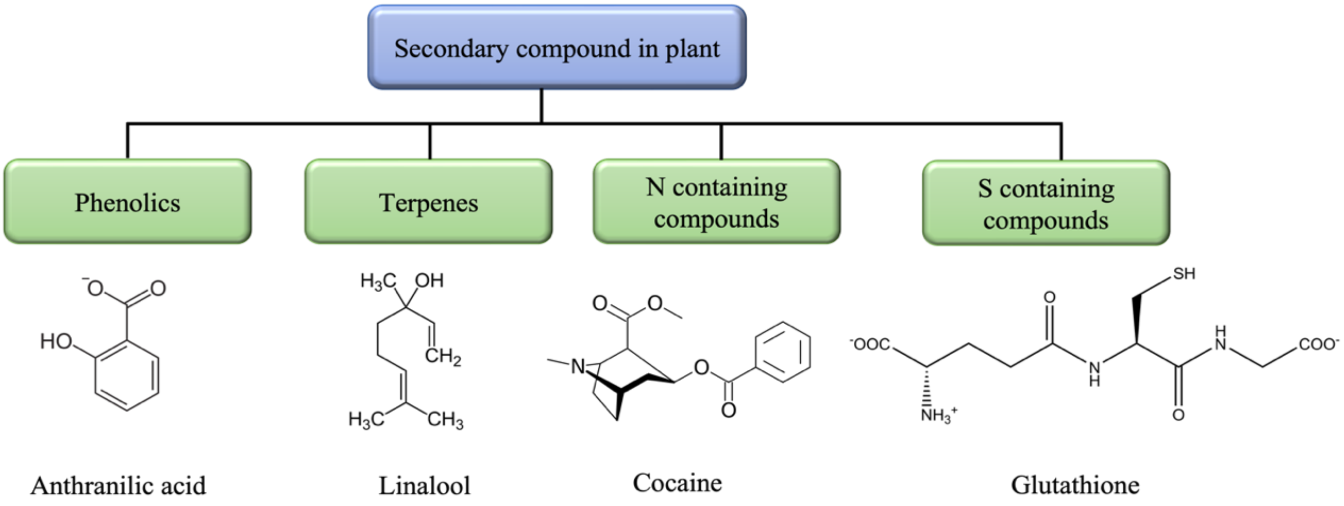

Fig. 1. Main secondary compound groups present in the plant

conditions, the content of key oil components including geraniol and citral rose. Similar to this, *Salvia officinalis* L. was shown to have increased concentrations of 2-camphanon bornan-2-on and (1S,4R,5R)-4-Methyl-1-(propan-2-yl)bicyclo[3.1.0]hexan-3-one when there was a slight water shortage (20). The treatment of drought stress lead to the content of essential oil constituents always rising. *Thymus vulgaris* L. thyme plants exposed to drought for 3 or 6 weeks have terpene concentrations up to 40% higher in their leaves than plants grown in well-watered conditions (21).

Nitrogen-containing compounds

Many plant secondary metabolites contain the element nitrogen. Alkaloids and glycosides comprise the bulk of the classification of nitrogen-containing secondary metabolites (13). These molecules are formed from amino acids like methionine, glycine, glutamine and so on (22). Under drought stress, it has been discovered that *Senecio jacobaea* G. has an enhanced total pyrrolizidine alkaloids concentration (9). In research on *Ricinus communis* L., it was shown that under salt stress, the amount of ricinine was much greater in the shoot than in the root (23). Light stress increased the synthesis of vinblastine and vincristine (indole alkaloids) in *Catharanthus roseus* L. (24). Metal stress conditions (Ag and Cd) stimulated the synthesis of scopolamine and hyoscyamine in *B. candida* P. (25). The concentration of cyanogenic glucosides is enhanced under drought stress conditions in *Phaseolus lunatus* L. (9).

Sulfphur containing compounds

To safeguard cells from harmful free radicals like ROS, oxidized glutathione undergoes a permanent reduction by GSH reductase to become γ-L-glutamyl-L-cysteinylglycine using nicotinamide adenine dinucleotide phosphate (27). The levels of total glutathione and its redox state were linked to growth under conditions of salt stress (26). When faced with stress, cysteine, and cystine redox seem to play a significant role in regulating thiol-disulfide and maintaining ROS scavenging and oxidative stress signaling, indicating their potential as intracellular redox regulators involved in stress signaling (26). Methionine, like cysteine, has various functions in cellular metabolism, including being a component of proteins, starting the translation of mRNA begins with S-adenosylmethionine, which also serves as a regulatory molecule (26). Methionine metabolism is vulnerable to stress, as evidenced by the over-expression of a gene involved in methionine biosynthesis that has been found to promote salt tolerance (27). Also, a correlation between the activity of methionine adenosyltransferase content was seen in tomatoes, where salt stress considerably raised the level of SAM-S. Glucosinolates are a different class of S-containing substances. Drought and light stress causes an increase in glucosinolate content in *B. oleracea* L., *B. carinata* L., *T. majus* L., *E. Sativa* L. and *D. Tenuifolia* L. (10, 26).

Conclusion

The plant is frequently subjected to various biotic and abiotic environmental challenges in the field. The conversion of stress, a negative stimulus, into benefits for the plant, such as increased secondary chemical content, is essential. Clear demonstrations of how stress might improve crop quality will significantly advance agriculture. Unfortunately, there needs to be more information on how stress is applied in practice and its potential for producing secondary compounds. In this review, pertinent literature on the effect of stress on secondary compound production was gathered and summarized to better understand this problem.

Authors' contributions

VHP and TTT drafted the manuscript. TTT participated in manuscript editing and coordination. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None.

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