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Research Progress on the Tolerance of Abscisic Acid in Plants to Abiotic Stresses

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Abstract **Review Article**

The growth and development of plants are inhibited by abiotic stresses, which is one of the factors limiting crop yield. Abscisic acid (ABA) is an important plant hormone that plays a crucial role in plants' response to abiotic stresses. In this review, abscisic acid was introduced from its discovery, distribution and transportation. The role of abscisic acid in abiotic stresses such as drought stress, salt stress and high temperature stress was discussed. Finally, the summary and prospect are summarized.
Keywords: Abscisic acid, Abiotic stresses, Phytohormone.

1. INTRODUCTION

The growth and development of plants are influenced not only by biological factors, but also by various abiotic stresses. Abiotic stresses refer to environmental conditions that are unfavorable for plant growth, including high temperature, low temperature, water shortage, salt, and high light intensity. [1]. Abiotic stresses affect plant growth, development, and productivity [2], alter plant morphology [3], and reduces photosynthesis [4]. It has the potential to cause a significant loss of approximately 51%-82% in the yield of major global food crops [5].

Abscisic acid (ABA) is one of the five major plant hormones [6], playing a crucial role in regulating various growth and development processes such as seed dormancy and germination [7]. It is also a key hormone in plant responses to abiotic stress [8] and is referred as a stress hormone [9]. This review describes abscisic acid and summarizes its role in responses to drought stress, salt stress, and high temperature stress, thereby highlighting the critical importance of abscisic acid in enhancing plant resistance to abiotic stress.

2. ABSCISIC ACID

2.1 Discovery of abscisic acid

Abscisic acid refers to a class of metabolites known as isoprenoids (also termed terpenoids) [10]. In 1963, Philip Wareing isolated a growth-inhibiting substance from the buds of *Acer platanoides* and named it dormin [11]. In the same year, Frederick Addicott identified a substance that regulates the abscission of young cotton (*Gossypium hirsutum*) fruits and named it abscisin II [12]. Subsequently, it was revealed that the chemical structures of dormin and abscisin II were identical, indicating that they were the same compound, which was designated as abscisic acid [13,14].

2.2 Distribution of abscisic acid

Abscisic acid is widely distributed in all higher plants [15] and is extensively distributed throughout plant tissues and organs [16]. Plant organs such as leaves, roots, flowers, and fruits are capable of synthesizing abscisic acid [17]. In tissues and organs that are about to fall off or enter a dormant state [18], as well as in plants under stressful environmental conditions [19], the content of abscisic acid is relatively high. For instance, under drought stress, the content of ABA in plants increases to enhance their stress resistance [20,21].

2.3 Transportation of abscisic acid

Abscisic acid is mainly transported in a free form [22], capable of long-distance transport [23]. It can be transported over long distances through the phloem and xylem [24]. For example, ABA can undergo long-distance transport through the xylem and phloem in plant shoot and root [25]. Abscisic acid can also undergo short-distance transport, which predominantly takes place between cells, encompassing vascular cells and guard cells, among others [26]. ABA may undergo translocation from the biosynthesis sites to the guard cells [27], such as from vascular tissues to guard cells [28]. The translocation of ABA among cells, tissues, and organs plays a pivotal role in the plant's overall physiological response to stressful conditions [29].

3. ABSCISIC ACID AND ABIOTIC STRESSES

3.1 Abscisic acid and drought stress

Drought is a recurrent extreme climate event on land, which is destructive to both the economy and ecology [30]. Drought stress has a significant negative impact on the growth and development of plants, which will make plants appear short, yellow leaves, withered branches and other phenomena.

Abscisic acid is a metabolic anti-transpirant [31], which typically plays a crucial role in plants' response to drought [32]. When plants suffer from drought stress, their ABA content will increase [33]. Under drought stress, abscisic acid (ABA) can regulate stomatal opening and closing. ABA-mediated stomatal closure reduces water loss by decreasing transpiration rate, and also enhances the water absorption and ion exchange capacity of the roots, enabling plants to better cope with arid environments and develop resistance to drought [34,35]. In addition, abscisic acid under drought conditions can also cause changes in the content of osmotic adjustment substances and osmotic adjustment capacity. Research by Zhou Lin *et al.* has shown that exogenous ABA treatment can increase the content of proline, soluble sugar, and soluble protein in tea plants under drought stress, reduce the damage caused by drought stress to tea plant seedlings, and thereby enhance their drought resistance [36]. Studies by Wang Wei *et al.* have shown that exogenous ABA can enhance the osmotic adjustment capacity of maize seedling leaves under drought conditions, which plays a certain role in improving the drought resistance of maize [37]. Abscisic acid can regulate plant stress resistance by regulating the expression of drought-resistant genes [38] and enhancing the activity of antioxidant enzymes in plant cells [39]. Relevant research indicates that under drought conditions, the early seedlings of *Onobrychis viciifolia* soaked in ABA exhibit higher activities of superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT) compared to those not soaked in ABA. This suggests that ABA can enhance the antioxidant enzyme activity of *O. viciifolia* under drought stress, mitigating the oxidative damage caused by drought stress [40]. Under drought stress, ABA also alters plant morphology to resist the damage caused by drought. Studies have found that under drought stress, the plant height, leaf area, root length, and root area of maize seedlings treated with exogenous ABA are significantly increased compared to those without ABA treatment, indicating that ABA can alleviate the damage caused by drought stress to maize seedlings [41].

3.2 ABSCISIC ACID AND SALT STRESS

Salt stress is one of the most common abiotic stresses in plants. At the same time, it is also the main abiotic stress that restricts plant growth and development [42]. Under salt stress, plant growth slows down, plant height decreases, and leaves turn yellow [43], which is similar to the situation of drought and water shortage. When plants are subjected to salt stress, the transcription level and expression level of ABA synthesis-related genes increase, leading to a substantial synthesis of ABA in the plant to adapt to salt stress [44]. ABA can maintain water balance and alleviate osmotic stress and ionic stress caused by excessive salt content [6]. The study on seedlings of *Toona sinensis* showed that the salt stress of external application of abscisic acid could effectively inhibit the absorption of salt ions by plants and enhanced their absorption of other nutrient ions, thus achieving ion balance, alleviating the salt stress inhibition of *T. sinensis* seedlings and resisting the harm of salt stress [45]. Under salt stress, ABA can also promote the accumulation of small organic molecules such as proline and soluble sugars in plants, thereby enhancing their salt tolerance [46]. Liu Xu and his colleagues found that exogenous ABA treatment can increase the content of proline and soluble sugar in eggplant seedlings under salt stress, enhance their osmotic adjustment ability, and enable them to better adapt to salt stress environments [47]. ABA can enhance the antioxidant defense system of plants by increasing the activity of oxidases (such as SOD, CAT, POD, etc.) to eliminate ROS and alleviate oxidative damage caused by salt stress to plants [48]. Related studies showed that the activities of SOD, POD and CAT in tomato seedlings under salt stress for 6 days were significantly lower than those under salt stress with exogenous ABA, which indicated that ABA was involved in scavenging active oxygen and improving the salt tolerance of tomato seedlings [48].

3.3 Abscisic acid and high temperature stress

High temperature stress refers to an abiotic stress that the temperature exceeds the suitable temperature for plant growth and development, thus causesplant damage [49]. High temperature stress will limit plant growth [50], lead to premature senescence and reduce photosynthetic efficiency [51]. Research on wild Kentucky bluegrasses under high temperature stress has found that under such stress, the water content of wild Kentucky bluegrasses leaves treated with abscisic acid is higher than that of untreated leaves, indicating that ABA can mitigate the damage of high temperature stress to wild Poa pratensis [52]. Under high temperature stress, abscisic acid increases the activity of antioxidant enzymes and removes ROS, thus reducing oxidative damage [53]. Related studies showed that the accumulation of ROS in rice buds with ABA application was significantly lower than that without ABA application, and the content of H_2O_2 was also reduced, and the ROS scavenging genes such as *OsFe-SOD* and *OsCu/Zn-SOD* were significantly up-regulated [54]. This indicates that ABA increases the activity of antioxidant enzymes to clear excess ROS. Abscisic acid can also bind to receptors on the biofilm through signal transduction, increase the stability of the membrane system, and reduce the degree of damage to the cell membrane by high temperature [55].

4.Summary and prospect

This study reviews the discovery, transportation, and distribution of abscisic acid, and analyzes its role in plant abiotic stress, aiming to elucidate the importance of abscisic acid in plant resistance to abiotic stress. Abscisic acid holds broad application prospects in enhancing plant stress resistance, particularly in drought, salt, and high temperature conditions. In addition, abscisic acid can also enhance the yield and quality of plant fruits. Relevant research has shown that exogenous application of abscisic acid can increase the concentration of carotenoids and soluble sugars, and reduce the concentration of organic acids in tomato fruits, thereby improving tomato fruit quality [56]. In fruit tree production, abscisic acid (ABA) is involved in the ripening process of fruits, which not only affects the appearance characteristics of the fruits but also makes the fruits easier to detach from the branches and facilitate harvesting [57]. Therefore, we can utilize genetic engineering techniques such as CRISPR-Cas9 and related technologies to improve the ABA signal transduction pathway [58,59], knock out or edit genes that are not conducive to ABA synthesis to increase the content of abscisic acid in plants, thereby enabling plants to better adapt to stressful environments and ensuring better yield and quality of plants.

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