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Research Progress of Abscisic Acid in Abiotic Stress of Plants

Li Luo[1], Xuefei Li[1], Jiayi Tan[1], Wenrui Liu[1], Fuquan Ye[1], Zhangyuan Hu[1], Jia Tian[1*]

[1]College of Life Science and Technology, Heilongjiang Bayi Agricultural University, Daqing 163319, China

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***Corresponding author:** Jia Tian
College of Life Science and Technology, Heilongjiang Bayi Agricultural University, Daqing 163319, China

Abstract **Review Article**

The growth and development of plants are inhibited by abiotic stress, which is one of the factors limiting crop yield increase. Abscisic acid (ABA) is an important plant hormone and plays a key role in plants' response to abiotic stress. This study summarized the role of abscisic acid in abiotic stress of plants, introduced abscisic acid from its discovery, distribution and transportation, discussed the role of abscisic acid in abiotic stress from three aspects: drought stress, salt stress and high temperature stress, and prospected the application prospect of abscisic acid in agriculture, in order to lay a foundation for further research on abiotic stress of plants and provide theoretical reference for workers engaged in agricultural production and related research.

Keywords: Abscisic acid, Abiotic stress, Role.

1. INTRODUCTION

In nature, as the basic producer of ecosystem, the growth and development of plants are not only affected by biological factors, but also faced with various abiotic stresses at all times. Abiotic stress refers to various pressures caused by abiotic environmental factors that adversely affect the growth and development of organisms. Salt stress, drought stress, high temperature stress, low temperature stress, enhanced ultraviolet radiation, nutritional deficiency and excess are all abiotic stresses. Abiotic stress will inhibit plant growth, change morphology to a certain extent, and hinder photosynthesis.

Agriculture is a fragile industry that is most sensitive to climatic and environmental conditions and most dependent on resources. With the increasing harm of abiotic stress on plants, the yield of crops has also been significantly affected. China and the world lose crops every year, and the world loses hundreds of billions of dollars every year, and China loses billions or even billions of dollars every year.

Abscisic acid is a kind of plant hormone and one of the five major hormones in plants [2], which is widely found in plants and has an important impact on plant growth and development and coping with environmental stress. It not only plays a role in physiological processes such as seed dormancy, plant growth inhibition and organ senescence [3], but also actively participates in the response of plants to various abiotic stresses, and is recognized as a resistance hormone. This study described abscisic acid, summarized the role of abscisic acid in drought stress, salt stress and high temperature stress, discussed its role in abiotic stress, and prospected the application prospect of abscisic acid in agriculture from two aspects: agricultural biotechnology strategy and the application prospect of abscisic acid in cultivating stress-resistant crops and improving crop yield and quality, in order to clarify the importance of abscisic acid in plant stress resistance, lay a foundation for further research on plant abiotic stress resistance, and engage in agricultural production and related research.

2. Discovery and Distribution of Abscisic Acid

2.1 Discovery of Abscisic Acid

In 1950s, people gradually paid attention to the effects of growth-inhibiting substances on abscission and dormancy, and it was generally believed that phenolic compounds were the main growth regulators of plants. In 1963, Addicott and others in the United States found a substance from cotton bolls that could significantly promote the petiole shedding of cotton seedling explants, called exfoliating abscicin II. Wareing and others in Britain also purified a substance from the leaves of maple trees that are about to enter dormancy in autumn, which can control the dormancy of deciduous trees and is called dormancy element. In 1965, it was confirmed that exfoliating element II and dormancy element have the same structure and are the same substance, and they are named abscisic acid.

2.2 Distribution of Abscisic Acid

Abscisic acid exists in two forms in plants, namely free form and bound form. Abscisic acid exists in vascular plants, including angiosperms, gymnosperms and ferns, and is found in various organs and tissues of higher plants. Abscisic acid is widely distributed in plants, and its content is high in seeds, mature and dormant seeds, leaves, root tip areas and fruits. Abscisic acid can also be synthesized in stems and flowers [4], but the content in stems and flowers is less. The abscisic acid content is higher in tissues and organs that are about to fall off or are about to enter dormancy and plants under adverse conditions. Such as drought and high light, the ABA content in plants will increase to enhance the ability of plant to resist stress.

3. Transportation of Abscisic Acid

Abscisic acid is mainly transported in free form, and some of it is transported in the form of abscisic acid glycoside. It is non-polar transport and can be transported through both xylem and phloem. The transportation speed of abscisic acid is fast, and the transportation speed in stems and petioles is about 20 mm per hour. There are both short-distance and long-distance transportation processes of ABA in plants, and abscisic acid can be transported through phloem and xylem for a long distance, from synthetic parts (such as leaves) to functional parts (such as roots). It can also be transported in local areas of plants, such as from cell to cell or from tissue to tissue.

4. Abscisic Acid and Abiotic Stress

4.1 Abscisic Acid and Drought Stress

As one of the most common natural disasters in the world, drought poses a serious threat to the natural environment and agricultural production [5]. Drought stress has a significant impact on the growth and development of plants. Under drought stress, plants appear short, withered leaves and branches, and so on. The water absorption of plants is also limited, and the swelling pressure of cells is reduced, which leads to the obstruction of cell elongation, and then the overall growth rate of plants is significantly slowed down. Abscisic acid is an ideal anti-transpiration agent. When plants suffer from drought stress, the ABA content in the body will increase rapidly, and the ABA increase in roots is earlier than that in leaves [6]. ABA reduces water evaporation by regulating the opening and closing of stomata, thus maintaining water balance in plants [7]. At the same time, ABA can also enhance the water absorption of roots and improve water conductivity, allowing plants to better cope with drought environments. ABA can promote the synthesis and accumulation of osmotic regulation substance, such as proline and soluble sugar, to adjust the osmotic potential in plant cells and improve the tolerance of plants to drought stress. Studies have shown that after exogenous ABA treatment, the proline content in roots and leaves of plants increased significantly [8], and the osmotic ability of leaves increased, thus increasing the water potential difference between roots and leaves and further enhancing the drought resistance of plants. The accumulation of ABA can also induce the expression of related genes, enhance the antioxidant capacity of plants, reduce the damage of free radicals to cells, and further improve the drought resistance of plants. Related studies showed that the contents of H2O2 and MDA in the early seedlings of sainfoin soaked by ABA were less than those in the early seedlings of sainfoin soaked without ABA. The activities of SOD, POD and CAT in the early seedlings of sainfoin soaked by ABA increased at first and then decreased, while the activities without soaking decreased significantly. This shows that ABA can alleviate the oxidative damage of sainfoin under drought stress, and also improve the antioxidant enzyme activity of sainfoin, thus alleviating the oxidative damage caused by drought stress [9]. Under drought stress, ABA can also adapt to the environment by regulating the growth and development of plants. For example, by inhibiting the growth of aboveground parts such as stems and leaves, water consumption is reduced; Promote the growth and development of roots, and enhance the water absorption capacity of plant roots to resist the damage caused by drought. It was found that under drought stress, the root length, root surface area and root surface area of maize with exogenous ABA increased significantly compared with that of maize without ABA [10].

4.2 Abscisic Acid and Salt Stress

Salt stress is one of the most common abiotic stresses, which is extremely harmful to plants. Under salt stress, the growth of plants is limited, the plants are short, the leaves are smaller and the color is dim, which is similar to drought and water shortage. At present, many studies have shown that there are many signals involved in plant stress response [11]. When plants suffer salt stress, the content of ABA in their bodies increases. ABA can regulate the ion balance inside and outside plant cells and relieve osmotic stress and ion stress caused by high salt concentration [12]. The study on Toona sinensis seedlings found that the salt stress of external application of abscisic acid can effectively inhibit the absorption of salt ions by plants and enhance their absorption of other nutrient ions, thus achieving ion balance, alleviating the salt stress inhibition of Toona sinensis seedlings and resisting the harm of salt stress [13]. At the same time, ABA can improve the osmotic pressure of plant cells by inducing the synthesis and accumulation of osmotic regulation substance (such as proline, soluble sugar, etc.) in plants, thus resisting the stress of high salt environment. ABA can enhance the antioxidant defense system of plants, remove excessive ROS by up-regulating the activities of antioxidant enzymes (such as SOD, CAT, POD, etc.), and protect cells from oxidative damage. 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, indicating that ABA was involved in scavenging active oxygen and improving the salt tolerance of tomato seedlings [14].

4.3 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 for a long time, thus causing plant damage. High temperature stress will inhibit the growth and development of plants, destroy the chloroplast structure in plant leaves, and also lead to burns, whitening, curling and premature aging of leaves, thus reducing the photosynthetic rate and effective photosynthetic area. Long-term high temperature stress may cause changes in the overall growth morphology of plants, such as compact plants, reduced branches, etc., and even lead to plant death. The study on high temperature stress of wild poa pratensis with abscisic acid showed that the leaf water content was higher than that without abscisic acid, which indicated that ABA could alleviate the damage of high temperature stress to wild poa pratensis [15]. Under high temperature stress, abscisic acid enhances the activity of the antioxidant enzyme system by inducing it, scavenging harmful substances such as reactive oxygen species produced by high temperature stress and reducing oxidative damage. 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 RS scavenging genes such as OsFe-SOD and OsCu/Zn-SOD were significantly up-regulated. This indicates that ABA increases the activity of antioxidant enzymes to clear excess Ros [16]. Exogenous abscisic acid can also promote the synthesis of heat-stable proteins in plants, increase the stability of cell membranes and reduce the damage of high temperature to cell membranes.

5. Application Prospect of Abscisic Acid in Agriculture

5.1 Agricultural Biotechnology Strategies

5.1.1 Genetic Engineering

With the continuous development of molecular biology technology, the content of abscisic acid (ABA) in crops can be increased or its ABA signal transduction pathway can be improved by genetic engineering. For example, by overexpressed ABA synthesis-related genes or signal transduction proteins, plants can enhance their tolerance to abiotic stresses such as drought and salt damage, optimize their growth and development processes, and ultimately improve crop yield and quality.

5.1.2 Gene Editing

In addition to genetic engineering technology, we can also use gene editing technology such as CRISPR-Cas9 to knock out or edit the negative regulatory genes in ABA signaling pathway, and accurately regulate the expression of ABA-related genes, thus improving the stress resistance of crops.

5.2 Application Prospect of Abscisic Acid in Cultivating Stress-Resistant Crops and Improving Crop Yield and Quality

5.2.1 Cultivate Stress-Resistant Crops

Abscisic acid plays an important role in plant stress resistance and has broad application prospects in cultivating stress-resistant crops. Controlling the content of abscisic acid by means of genetic engineering and gene editing technology can significantly enhance the tolerance of crops to abiotic stresses such as drought, salinity, low temperature and high temperature, enhance the resistance of crops to abiotic stresses, and provide guarantee for agricultural production. At the same time, abscisic acid can be used to cultivate new crop varieties with specific stress resistance.

5.2.2 Improve Crop Yield and Quality

Abscisic acid is also of great significance in improving crop yield and quality. Abscisic acid can participate in regulating the growth and development of crops, such as promoting the development and maturity of seeds and promoting the development of roots, so as to improve the quality characteristics of crops. For example, in fruit tree production, abscisic acid participates in the fruit ripening process, which not only affects the appearance characteristics of the fruit, but also makes the fruit easily detached from the branches and easy to pick [17]. The application of exogenous abscisic acid can promote the regulated synthesis with ethylene and thus promote the ripening of fruits; at the same time, it promotes sugar accumulation and improves the taste and nutritional value of fruits.

6. CONCLUSIONS

This study summarized the discovery, transportation and distribution of abscisic acid, and analyzed the role of abscisic acid in abiotic stress of plants. The application prospect of abscisic acid in agriculture was prospected in order to clarify the importance of abscisic acid in plant resistance to abiotic stress, lay a foundation for the research of plant resistance to abiotic stress, and provide relevant reference for relevant personnel and agricultural producers.

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