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Research progress on regulation of plant stress resistance by melatonin

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Abstract
As a signaling molecule, melatonin can regulate plant circadian rhythm, seed germination, root and flower development, and enhance plant resistance to various stresses. In this paper, the regulatory role of melatonin in plant abiotic stress and biological stress response was summarized, and the application prospect of melatonin in plant growth and development and stress resistance was prospected, in order to provide reference for improving plant stress resistance by using melatonin.

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1. Introduction

Melatonin, also known as n-acetyl-5-methoxytryptamine, is a natural bioactive indoleamine molecule, widely existing in seeds, leaves, fruits, flowers, roots and other tissues of plants, with the function of regulating plant growth and development [1]. Melatonin is an antioxidant that can remove excessive reactive oxygen species induced by abiotic and biological stresses, improve antioxidant defense ability, and play an important role in protecting plants against drought, salt, heavy metals, cold, heat, ultraviolet and other stresses. In addition, melatonin is a signaling molecule that enhances plant resistance to abiotic and biological stresses by activating the expression of stress-responsive genes. In this paper, the recent studies on the regulation of melatonin on plant growth, development and stress resistance were summarized, focusing on the physiological functions of melatonin in plant growth and development, abiotic and biological stress response regulation.

2. Melatonin regulates the physiological functions of plant growth and development

As a growth regulator and signaling molecule, melatonin is involved in regulating many biological processes involved in plant growth and development, including seed germination, root development, leaf senescence, etc

Studies have shown that melatonin plays an important role in improving seed vitality and promoting seed germination [2]. Exogenous melatonin effectively alleviated the inhibition of drought stress on the germination of seedless brome and salt stress on the germination of aged oat seeds, significantly increased the germination rate of seeds, increased the contents of free proline and soluble protein in seedlings, increased the activity of superoxide dismutase, and decreased the content of malondialdehyde. The results indicated that melatonin could promote germination of seeds under drought stress, salt stress and aging treatment.

It was found that the promotion effect of low melatonin concentration on the initial rooting elongation of *Arabidopsis thaliana* was related to the overexpression of hormone, cell wall and developmental pathway genes induced by indole-3-acetic acid, and depended on the existence of IAA polar transport [3]. The inhibitory effect of high concentration of melatonin on the growth of primary roots was related to the expression of genes related to JA, brassinosteroid, cytokinin and auxin biosynthesis.

Exogenous melatonin alleviated the effect of barley leaf senescence. It was found that the loss of chlorophyll in leaves was significantly reduced, and the senescence degree of leaves was effectively alleviated.

Exogenous melatonin also inhibited the dark induced senescence of Lolium perenne leaves, reduced the transcription level of genes related to chlorophyll degradation and senescence, improved chlorophyll content and photochemical efficiency, significantly reduced the endogenous reactive oxygen production rate and H2O2 content in isolated leaves, increased SOD and catalase activities and transcription levels, and maintained good cell membrane stability [4].

3. Cold stress

The low temperature and cold conditions during plant growth and development will seriously restrict the material metabolism and life events, and melatonin can regulate the response of plants to low temperature stress, and play an important role in enhancing the low temperature tolerance of plants. Leaf melatonin spray significantly increased the fresh weight of perennial ryegrass seedlings under low temperature stress, decreased the relative electrical conductivity, MDA content and ROS accumulation in leaves, and increased the activities of CAT, ascorbate peroxidase and glutathione reductase as well as the levels of proline and endogenous melatonin, suggesting that exogenous melatonin alleviated the damage caused by low temperature on seedlings and enhance its cold resistance [5].

4. High temperature stress

In recent years, melatonin has also been shown to play an important role in enhancing plant resistance to high temperature stress. It was found that exogenous melatonin inhibited the expression of senescence related genes and ABA biosynthesis genes in perennial ryegrass, activated the expression of CTK biosynthesis genes, and increased the contents of endogenous melatonin and CTK, thus alleviating the growth inhibition and leaf senescence induced by heat stress. Melatonin also improved the heat resistance of creeping bentgrass, decreased the lipid peroxidation of leaves, increased the activities of SOD and POD, and changed the content of fatty acids [6].

5. Drought stress

As an antioxidant, melatonin alleviates the damage caused by drought stress on grass seedlings and plants. It was found that leaf spraying with melatonin significantly improved root growth indexes (surface area, average diameter, length, root activity and lateral root number, etc.), increased root-shoot ratio and dry-fresh ratio, decreased leaf relative electrical conductivity and MDA content, and improved drought resistance of tall fescue seedlings. The above ground fresh weight, relative water content of leaves, soluble sugar, soluble protein and free proline contents of leaves were significantly increased under drought stress by spraying melatonin on leaves, indicating that melatonin could improve drought resistance of seedlings by improving water physiology of leaves.

6. Flooding stress

In plants, there is an antagonistic effect between melatonin and ethylene, which can inhibit ethylene biosynthesis and improve plant adaptability to waterlogging stress. The metabolic pathways related to carbohydrate and amino acid were activated under waterlogging stress, and the ethylene content was significantly increased. The appropriate concentration of exogenous melatonin alleviated the symptoms of waterlogging damage of alfalfa, promoted polyamine synthesis, reduced ethylene content, enhanced cell membrane stability and improved photosynthetic efficiency, suggesting that melatonin alleviated the damage of waterlogging stress on alfalfa by regulating ethylene synthesis. And enhanced its waterlogging tolerance.

7. Salt stress

It was found that the activity of antioxidant enzymes and the content of osmoregulatory substances in alfalfa seeds were increased under salt stress, the content of lipid peroxidation product MDA was decreased, and the seed germination ability was enhanced under salt stress. Salt stress also decreased the antioxidant capacity and photosynthetic efficiency of alfalfa seedlings, while exogenous melatonin significantly increased POD and SOD activities, decreased relative conductivity and MDA content, and increased chlorophyll a content, chlorophyll b content, net photosynthetic rate, stomatal conductance and transpiration rate. The results indicated that melatonin enhanced the salt-tolerance of alfalfa seedlings by increasing antioxidant capacity and photosynthetic efficiency. Similar results were reported in the study of melatonin improving salt tolerance in Bromus catharticus. Melatonin also enhanced the contents of ACC and ACO in alfalfa seedlings under salt stress, suggesting that the enhanced salt-tolerance of alfalfa may be closely related to the regulation of ethylene biosynthesis by melatonin.

8. Looking forward

Although the content of melatonin in plants is very low, it plays a crucial role in plant response to various abiotic stresses (drought, salt, low temperature, high temperature, heavy metals, etc.) and biological stresses. With the deepening of research on plant melatonin, its physiological function and mechanism of regulating plant growth and development have been gradually revealed. However, compared with traditional crops, the research on the regulation of growth and development and stress resistance of cash crops by melatonin is still very limited, and there are still some problems that need to be further explored and solved.

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