COMMENTARY

Role of ascorbic acid in mitigating abiotic stress in plants

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DESCRIPTION

Over production of reactive oxygen species (ROS) in plants under stress conditions is a common phenomenon. Plants tend to tackle this problem through their ability to synthesize ROS neutralizers, including non-enzymatic and enzymatic antioxidants. Both the non-enzymatic and enzymatic components of the antioxidant defense system detoxify or scavenge ROS and reduce their harmful effects. In this regard, ascorbic acid (AsA) is a universal non-enzymatic antioxidants, with great potential not only to scavengate ROS, but also to regulate many fundamental functions of plants in both stressed and unstressed states.

Role of ascorbate in oxidative defense metabolism

Ascorbate is thought to be able to effectively regulate the antioxidant metabolism of plants, and glutathione ascorbic acid pair is involved in the regulation of plant developmental processes by manipulating oxidative metabolism.

Ascorbate is an essential metabolite involved in important cellular functions. The pathway of ascorbic acid synthesis in plants is still fully investigated and it is surprising that it is involved in various intermediate products: GDP-mannose, GDPL-galactose, L-galactose and L-galactono 1,4 lactose. Glutathione (GSH), on the other hand, acts as an antioxidant by removing ROS and is involved in the ascorbic acid-glutathione cycle, which removes harmful peroxides. Two enzymes catalyze the synthesis of glutathione: glutamate-cysteine ligase and glutathione synthetase. Both AsA and GSH are found in the cytosol, cell nucleus, chloroplasts, mitochondria, and peroxisomes.

The Ascorbate-glutathione pathway is the most important pathway of antioxidant defense. The Ascorbate-glutathione (AsAGSH) pathway, also known as the Asada-Halliwell pathway, is composed of AsA, GSH, and four enzymes. ascorbate peroxidase, monodehydroascorbate reductase, dehydroascorbate reductase, and glutathione reductase plays important roles in the detoxification of ROS. In addition to detoxifying ROS, they also interact with other plant defense systems to protect plants from damage induced by various abiotic stresses. Some plant studies have shown that upregulating or overexpressing enzymes in the AsAGSH pathway and increasing AsA and GSH levels increases plant resistance to abiotic stress by reducing ROS.

Excessive ROS induced by abiotic stress causes oxidative stress in plants, followed by cell damage and even death. Therefore, the plant itself protects against this higher ROS accumulation through its defense mechanism. Plants significantly activate the AsA-GSH pathway to ROS detoxification.

Various abiotic stresses

Salinity: Salinity is one of the most devastating abiotic stressors. Salinity persuades the accumulation of acute ROS, then disrupted cell redox, followed by cell damage such as membrane dysfunction, DNA damage, disruption of enzyme activity, and distractions of antioxidant defense systems. At this point, the plant synthesis of cellular AsA and GSH, they act as non-enzymatic antioxidants by incorporating enzymatic components and detoxifying ROS to acceptable levels.

Drought: Drought is another major abiotic stress that causes excessive ROS accumulation, causing changes in the enzymatic activity of the AsAGSH pathway for ROS detoxification. The enzymatic response of the AsAGSH pathway depends on the plant species, plant age, drought intensity, and duration.

Toxic metals/metalloids: Exposure to toxic metal/metalloids has become a formidable problem for plant growth and development. Plants experience toxic metal/metalloid stress and try to survive to some extent using established antioxidant defense systems. However, the activity and performance of the immune system depends on the concentration of stress, the duration of stress, the type of plant, and the age of the plant. The AsA-GSH pathway enzyme has confirmed different responses to different toxic metals/metalloids.

Extreme temperature: Generally, a temperature rise above the optimum growth temperature of any plant species by 5°C is considered extreme temperature stress or HT stress or heat shock. Heat stress causes denaturation of proteins and membrane lipids, inactivation of enzymes, inhibition of protein synthesis, and loss of membrane integrity. This is due to the disruption of cell homeostasis by ROS formed in large quantities under thermal stress.

Flooding: Ecosystem changes can lead to extinction of plant species and imbalances in the natural environment. So far, many studies have demonstrated flood-induced ROS generation followed by cell damage.

Atmospheric pollutants: Plants grown under different levels of atmospheric pollution show different ways of responding to oxidative stress and regulating the AsA-GSH pathway.

CONCLUSION

Ascorbic acid (AsA) is an antioxidant molecule and an important substrate for detoxifying reactive oxygen species. The physiologically active form of AsA is the resonance-stabilized anionic form (formed by the deprotonation of the hydroxy group of C3), known as ascorbate.

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