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ABA (Abscisic Acid): Role of Stress Hormone Regulate the Plant Growth and Development

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Abstract

Abscisic acid is one of the stress hormones that stimulate rather than inhibit the plant growth. It has an essential role in multiple physiological processes of plants, such as seed germination, seed development, dormancy, vegetative growth, and environmental stress responses, cuticular wax accumulation, stomatal closure, bud dormancy, osmotic regulation, growth inhibition and leaf senescence among many others. Its occurrence in dicots, monocots, gymnosperms and some ferns. Generally, fruits and seeds contain the highest amount of Abscisic acid. It is synthesized in the leaves from where it is translocated to the stem apex through phloem. The name of hormone "abscisic acid" was given because it was found in high concentrations in newly abscessed or freshly fallen leaves.

Keywords: ABA, stress hormones, growth and development.

Introduction

Abscisic acid (ABA) is the plant stress hormone that is usually associated with major plant responses to environmental stress. Earlier in 1940s, scientists Hemberg started searching for hormones that would inhibit growth and development and named dormins (Hemberg, 1949a). In 1960s, Philip Wareing confirmed that application of a dormin to a bud Would induce dormancy. F.T. Addicott discovered that this substance stimulated abscission of cotton fruit. He named this substance abcisin II. (Subsequent research showed that ethylene and not abscisin controls abscission. In 1964, it becomes evident that the three groups had discovered the same plant hoemone. Later on, the name was changed to abscisic acid (ABA).

Abscisic acid is a sesquiterpene consisting of 15-Carbon atoms (Figure 1). It is unique among plant hormones in having an asymmetric carbon atom. It has a six-carbon ring structure ring to which a side chain is attached. Because of the asymmetric carbon atom (carbon-1), it occurs in two enantiomorphic forms, R-abscisic acid and S-abscisic acid. The naturally occurring form is S-abscisic acid (Hemberg, 1949b).

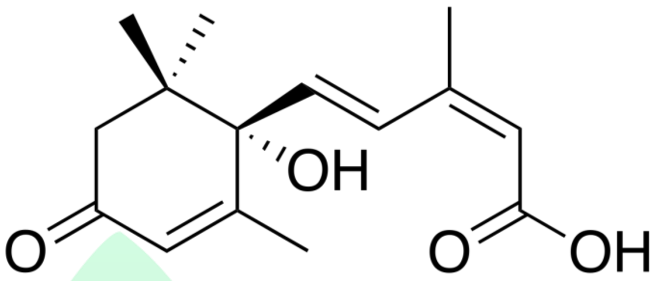

Figure 1 Chemical Structure of Abscisic Acid

Mechanism of Action of ABA

Abscisic acid has an unique mode of action (figure 2) which is effect the growth and development of plant at different stage and in response to different environmental conditions. It helps in plant to overcome different stress during its growth period to completing life cycle of plant.

- ✓ ABA binds to receptor
- ✓ Form Reactive oxygen species (ROS)
- ✓ Activate Ca^{2+} channels
- ✓ Intracellular Ca^{2+} goes up, Inhibit K^+ channels
- ✓ Membrane depolarization activates K^+ channels out
- ✓ Stomata closer

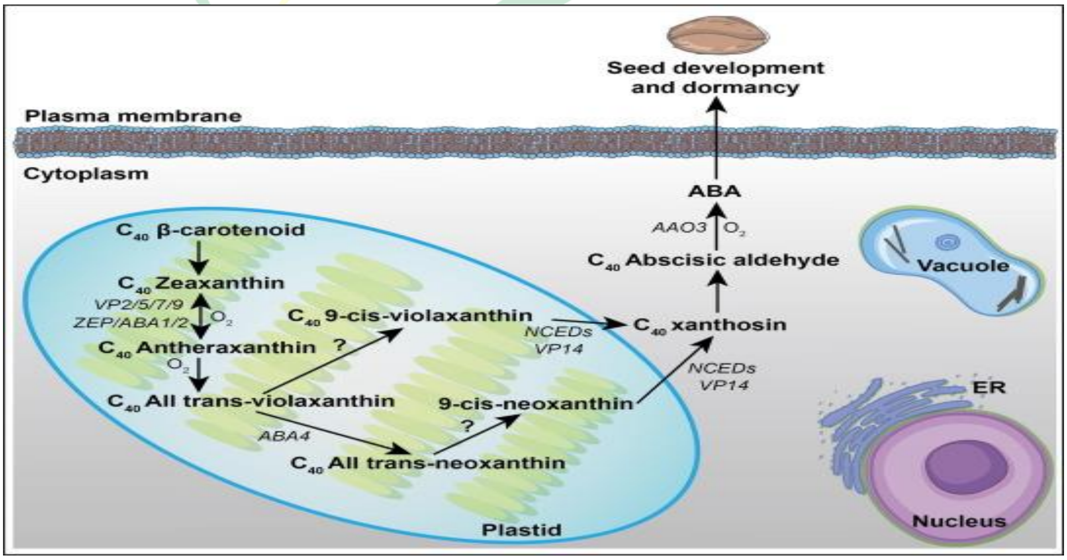

Figure 2 Mechanism of action

Physiological Roles of ABA

Drought Tolerance

- Abscisic acid is the key internal signal that facilitates drought resistance in plants.
- Under water stress conditions, ABA accumulates in leaves and causes stomata to close rapidly, reducing transpiration and preventing further water loss.
- ABA causes the opening of efflux K^+ channels in guard cell plasma membranes, leading to a huge loss of this ion from the cytoplasm.
- The simultaneous osmotic loss of water leads to a decrease in guard cell turgor presser with consequent closure of stomata.

Freezing Tolerance

- Elevated ABA levels arc associated with increased freezing resistance.
- ABA appears to mediate a plants response to environmental stresses such as freezing, by regulating gene expression.
- Certain genes are switched on by ABA while others are switched off.

Close the Stomata

- ABA plasma membrane receptor Mutants that lack the ability to produce ABA exhibit
- Permanent witling and are Called wilty mutants because of their inability to closer their stomata.
- Stomata closing can also be caused by ABA synthesized in the roots and exported to shoot.

Promote Seed Dormancy

- ABA plays a major role in seed dormancy growth of the seed suspended —"dormant seeds".
- Primary dormancy and secondary dormancy Controlled by the ratio of ABA to GA.
- Embryo dormancy is due to the presence of inhibitors, especially ABA, as well as the absence of growth promoters, such as GA.
- The loss of embryo dormancy is often associated with a sharp drop in the ratio of ABA to GA.

Induced dormancy of buds

- Dormant bud - shortened internodes and specially modified leaves — "BUD SCALES"
- Most of the trees - buds formed late summer and remain dormant throughout winter.

- Levels of endogenous ABA is high in herbaceous plant — eg. Potato

Promotes desiccation tolerance in the embryo

- An important function of ABA is developing seed - desiccation tolerance.
- Levels of ABA in seeds peak during embryogenesis.
- During the mid- to late stages of seed development specific mRNAs accumulate in embryos.
- These mRNAs encode lac-embryogenesis abundant (LEA) proteins.
- Synthesis of many LEA proteins induced by ABA treatment.

Inhibits Precocious Germination and Vivipary

- When immature embryos are removed from their seeds and placed in culture medium they germinate precociously.
- ABA added to the culture medium inhibits precocious germination this result, in combination with the fact that the level of endogenous.
- ABA is high during mid- to late seed development, suggests that ABA is the natural constraint that keeps developing embryos in their echogenic state.
- During seed development, embryos of monocot and dicot plants may fail to complete maturation and germinate while the immature seed is still attached to the maternal tissue.
- This phenomenon is referred to as vivipary or pre harvest sprouting.

Leaf senescence

- The deteriorative processes that naturally terminates their functional life referred to as “senescence”
- Expression of senescence associated genes (SAGs) increases
- hydraulic enzymes-proteases, ribo-nucleases, lipases
- ABA involve in senescence of leaves but not the abscission of leaves

Stop Starch Hydrolysis

- Abscissic acid inhibits gibberellin mediated alpha-amylase
- formation during germination of cereal grains and hence stop strach hydrolysis.

Root and shoot growth

- ABA promotes the root growth and inhibits shoot growth whenever there is a low water potential
- Under the dehydrating condition, when the ABA level are high the endogenous hormone exert a strong positive effect on the root growth by suppressing the ethylene production a slight negative effect on the shoot growth

Increase Hydraulic Conductivity

- ABA increase the hydraulic conductivity and Ion flux of a root in response to a water stress.
- Hydraulic Conductivity- decreasing the resistance of a water movement across the membrane

Geotropism

- There are sufficient evidences to support that ABA controls geotropic responses of roots.
- Appreciable amounts of ABA have been detected in maize root tips.
- The accumulation of ABA in the tip appears to require light and gravity.
- It is produced in the root cap, translocation basipetally and stimulates positive geotropic response by acting as inhibitor.

Flowering

- ABA acts as inhibitor of flowering in long day plants by counteracting the effect of gibberellins on flowering in these plants.
- On the other hand, ABA induces flowering in short day plants. e.g., Strawberry.

Cambium activity

- Abscisic acid stops mitosis in vascular cambium towards the approach of winter.

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