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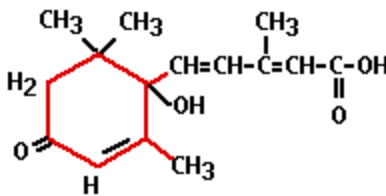
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# *Absciscic acid*

Absciscic acid (ABA) is often referred to as an inhibitory rather than stimulatory hormone. It is a single compound unlike the auxins, gibberellins, and cytokinins. It was called "abscisin II" originally because it was thought to play a major role in abscission of fruits. At about the same time another group was calling it "**dormin**" because they thought it had a major role in bud dormancy. The name absciscic acid (ABA) was coined by a compromise between the two groups. It is involved in the closure of stomata, bud and seed dormancy and is known to inhibit other hormonal actions. It is found in leaves (where it is partially synthesized), stems, and green fruits. and its biosynthesis is related to the process of carotenoid production. It is generally associated with negative-feedback interactions or stress-related environmental signals such as drought, freezing temperatures and environmental pollutants. So, it is also known as '**stress hormone**'.



**Absciscic acid (ABA)**

## *Discovery:*

F.T. Addicott and his associates discovered absciscic acid in the early 1960s in the process of studying abscission in cotton (commercially important for mechanization of cotton picking). Two compounds were isolated and called abscisin I and abscisin II. Abscisin II is presently called absciscic acid (ABA)(Addicot, 1963).

Two other groups at about the same time discovered the same compound. One group headed by Philip Wareing was studying bud dormancy in woody plants. The other group led by Van Steveninck was studying abscission of flowers and fruits from lupine. Plant physiologists agreed to call the compound abscisic acid (Salisbury and Ross, 1992). It was also being studied by other plant physiologists at the same time for its property of controlling abscission of flowers and in the initiation of dormancy of wood production.

### *Occurrence and Distribution of ABA in Plants:*

- Abscisic acid (ABA) is a **ubiquitous plant hormone in vascular plants**.
- In bryophytes, it has been found in mosses but not in liverworts.
- Some fungi synthesize ABA as secondary metabolites.
- ABA has not been detected in any algae. However, a 15-C organic compound called lunularic acid has been found in algae and liverworts that appears to be a possible functional equivalent of ABA in these plants.
- Within the plant, ABA has been detected in all major organs or living tissues from root caps to apical buds such as roots, stems, buds, leaves, fruits and seeds and also in phloem and xylem sap and in nectar.
- ABA is synthesized in all types of cells that contain chloroplasts or other plastids. It occurs predominantly in mature green leaves.

The concentration of ABA in specific plant tissues varies greatly at different developmental stages or in response to environmental conditions

especially water stress. For instance, in developing seeds ABA conc. may increase 100 fold within a few days and decline as the seed matures. Similarly, under water stressed conditions, ABA level may increase 50 fold in the leaves within a few hours and declines to normal when plant water potential is restored.

### *ABA Transport in Plant:*

The transport of endogenous ABA at various stages of growth in higher plants is not very clear. However, experiments made with <sup>14</sup>C-labelled ABA have shown that,

- (i) Externally applied ABA is able to get into tissues rapidly and is distributed freely in all directions within the plant;
- (ii) Cell to cell transport of ABA is slow and non-polar;
- (iii) ABA is present in phloem and xylem sap and is most probably **trans located throughout the plant through vascular tissue;**
- (iv) ABA synthesized in root cap moves basipetally into the central vascular tissue;
- (v) There is some evidence of lateral movement of ABA in root tips in response to gravity stimulus where it causes asymmetric inhibition of growth resulting in geotropic curvature.

i. Redistribution of ABA among plant cell compartments is controlled by pH gradient across the membranes. At low pH (6.3 or less) ABA exists in protonated or un-dissociated form (ABA<sup>H</sup>) which can readily cross most cell membranes. At higher pH (7.2 or more), ABA exists in dissociated form (ABA<sup>-</sup>) that is impermeant and cannot cross the membranes easily. ABA in protonated form tends to diffuse from a compartment with low or acidic pH into a compartment with high or alkaline pH. At higher pH, ABA<sup>H</sup> dissociates into ABA<sup>-</sup> and is trapped.

ii. ABA is known to be transported in plants mostly in its free form. However, ABA can also be transported to some extent in its conjugated form as ABA-β-D-glucosyl ester.

### *Biosynthesis of ABA in Plants:*

ABA is a naturally occurring compound in plants. It is a **sesquiterpenoid** (15-carbon) which is partially produced from **isopentenyl pyrophosphate or IPP** ( a xanthophyll intermediate) via the mevalonate pathway in chloroplasts and other plastids. Because it is synthesized partially in the chloroplasts, it makes sense that biosynthesis primarily occurs in the leaves. The production of ABA is accentuated by stresses such as water loss and freezing temperatures. It is believed that biosynthesis occurs indirectly through the production of carotenoids

Extensive studies done by researchers with ABA deficient mutants of tomato, *Arabidopsis* and other plants have clearly shown that ABA is synthesized in higher plants not from simple terpenoid precursors directly

through 15-C farnesyl diphosphate (FPP), but indirectly through carotenoid pathway as breakdown product of 40-C xanthophyll such as violaxanthin or neoxanthin (Fig. 17.31).

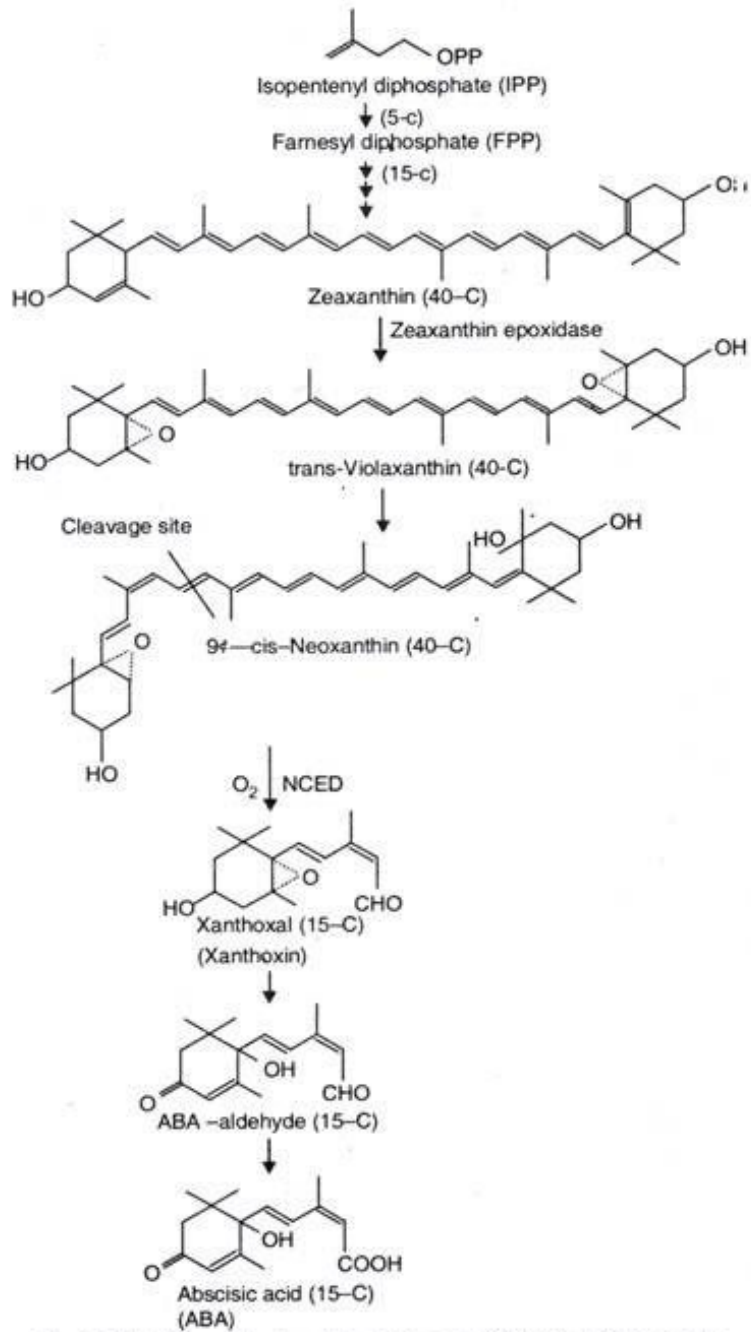


Fig. 17.31. Biosynthesis of abscisic acid (ABA) in higher plants.

- i. The initial steps of ABA biosynthesis take place in chloroplasts or other plastids while final steps occur in cytosol.
- ii. Violaxanthin is synthesized from zeaxanthin (also a 40-C xanthophyll) in a reaction that is catalysed by the enzyme zeaxanthin epoxidase (ZEP). This enzyme is encoded by ABA1 locus of Arabidopsis.
- iii. Violaxanthin is converted into 9'-cis-neoxanthin. The latter is then cleaved into a 15-C compound xanthoxal (previously called xanthoxin) and a 25-C epoxy aldehyde in the presence of the enzyme 9'-cis-epoxycarotenoid dioxygenase (NCED). (This enzyme can also catalyse cleavage of violaxanthin into xanthoxal and a 25-C allenic apoldehyde).
- iv. Xanthoxal (xanthoxin) is finally converted into ABA in cytosol via two oxidation steps catalysed by the enzymes aldehyde oxidases involving abscisyl aldehyde (and/or possibly xanthoxic acid) as intermediates. The enzymes aldehyde oxidases require Mo as cofactor.

### ***Physiological roles of Abscisic Acid:***

#### **1. Closure of Stomata:**

Large amounts of abscisic acid in the leaves causes the stomata to close which helps the plant conserve water during droughts. Reactions can be investigated within minutes of spraying. Commercially it is used in fields when droughts threaten. The mechanism:

- ABA binds to receptors at the surface of the plasma membrane of the guard cells.
- The receptors activate several interconnecting pathways which converge to produce
  - a rise in pH in the cytosol;
  - transfer of  $\text{Ca}^{2+}$  from the vacuole to the cytosol.
- These changes
  - stimulate the loss of negatively-charged ions (anions), especially  $\text{NO}_3^-$  and  $\text{Cl}^-$ , from the cell and also
  - the loss of  $\text{K}^+$  from the cell.
- The loss of these solutes in the cytosol reduces the osmotic pressure of the cell and thus turgor.
- The stomata close.

Stomatal closure can be caused by ABA produced in roots and exported to shoot (root- signal). Mutants that lack the ability to synthesize ABA to show prominent wilting and application of exogenous ABA in such mutants causes stomatal closure and restoration of turgor pressure.

## **2. Protecting cells from dehydration:**

ABA signaling turns on the expression of genes encoding proteins that protect cells — in seeds as well as in vegetative tissues — from damage when they become dehydrated.

## **3. Seed Dormancy:**

Abscisic acid delays seed germination in many plants. Seed dormancy is controlled by the ratio of ABA to GA. ABA has some effect on induction and maintenance of dormancy in general

- Induces seeds to synthesize storage proteins,
- Inhibits the effect of gibberellins on stimulating de novo synthesis of  $\alpha$ -amylase,

- Inhibit the synthesis of GA induced hydrolytic enzymes that are essential for the breakdown of food reserves in seeds.

The loss of embryo dormancy is often associated with a sharp drop in the ratio of ABA to GA. In desert plants, ABA found in the outer layer of the seeds must be washed away by rains in order for the seeds to germinate.

#### **4. Bud dormancy:**

ABA mediates the conversion of the apical meristem into a dormant bud. The newly developing leaves growing above the meristem become converted into stiff bud scales that wrap the meristem closely and will protect it from mechanical damage and drying out during the winter.

ABA in the bud also acts to enforce dormancy so if an unseasonably warm spell occurs before winter is over, the buds will not sprout prematurely. Only after a prolonged period of cold or the lengthening days of spring (photoperiodism) will bud dormancy be lifted.

#### **5. Promotes root growth but inhibits shoot growth at low water potential:-**

Under water stress conditions when ABA level is high, this endogenous hormone exerts a strong positive effect on root growth and a slight negative effect on shoot growth (by means of inhibiting cell division in the vascular cambium). The overall effect is an increase in root:shoot ratio at low water potential which along with the effect of ABA on stomatal closure, hence the plants to cope with water stress.

ABA also stimulates root growth in the direction of soil moisture, a phenomenon called **hydrotropism**.

## **6. Induces gene transcription :**

ABA induces gene transcription especially for proteinase inhibitors in response to wounding (role in pathogen defense).

## **7. Abscission**

ABA also promotes abscission of leaves and fruits (in contrast to auxin, which inhibits abscission). It is, in fact, this action that gave rise to the name **abscisic** acid.

The dropping of leaves in the autumn is a vital response to the onset of winter when groundwater is frozen, thus cannot support transpiration and snow load would threaten to break any branches still in leaf.

## **8. Seedling growth**

ABA inhibits stem elongation probably by its inhibitory effect on gibberellic acid.

## **9. Apical dominance**

Evidence from pea and *Arabidopsis* mutant studies suggest that an unidentified carotenoid derived /plastid- produced branching inhibitors which move acropetally from the roots to the shoots and interact with auxin in the control of apical dominance. Abscisic acid (ABA), a plastid-produced carotenoid derivative and a known inhibitor of plant growth, was postulated in the late 1970s as a possible auxin-induced second messenger that directly repressed axillary bud outgrowth (Tucker, 1978).

## **10. ABA promotes leaf senescence independently of ethylene:**

ABA was originally isolated as Abscisin i and Abscisin ii, as it promotes senescence. But at present ABA stimulates abscission of organs only in a few species and in others the primary hormone causing abscission is

ethylene. ABA on the hand is closely involved in leaf senescence without mediated through its stimulation of ethylene production.

### **11. Salt and cold stress :**

It has been proved that ABA level increases when plants are stressed by saline soil, by chilling and freezing temperature and in some species even by high temperature. In many cases applied ABA can partly reduce the plant's reaction to the stress factor. For e.g ABA hardens plants against frost damage. It is also noticed that Osmotin protein is produced during salt stress condition by the influence of ABA.

### **12. Promotes desiccation tolerance in the embryo:**

Level of ABA in seeds is high during embryogenesis. During the mid to late stages of seed development, specific mRNAs accumulated in embryos. These mRNAs encode so-called late- embryogenesis abundant (LEA) proteins. It is noted that synthesis of LEA proteins is induced by ABA treatment.

### **13. 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 inhibits precocious germination. This result, in combination with the fact that the level of ABA is high during mid- to late seed development, suggests that ABA is the natural constraint that keeps developing embryos in their embryogenic state. Thus it also inhibits viviparous germination.