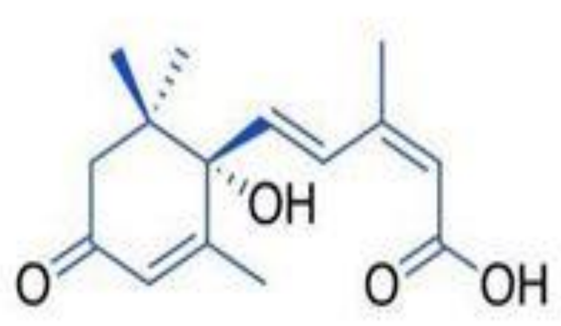
Unit 5.1

Abscisic acid- Discovery, Biosynthesis and Physiological Role

Abscisic acid is one of the most important plant growth inhibitor rather than stimulatory hormone. It is of general occurrence in monocots, dicots, 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 "abscisic acid" was given because it was found in high concentrations in newly abscissed or freshly fallen leaves..

Abscisic acid is a sesquiterpene consisting of 15-Carbon atoms. 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.



Chemical Structure of Abscisic Acid

Discovery

Torsten Hemberg (1940) reported that dormant potato tubers and buds of ash (*Fraxinus excelsior*) contained inhibitor (rather than stimulators) that blocked the effects of IAA. When the buds germinated, the amount of these inhibitors decreased. Eagles and Wareing (1963) isolated an inhibitor from the birch (*Betula pubescens*) leaves held under short day conditions. When this substance was reapplied to the leaves of birch seedlings, apical growth was completely arrested. As this substance induced dormancy, they named it as 'dormin'. Ohkum et. al. (1965) isolated an inhibitor from cotton fruits and named it 'abscisin II'. Cornforth and his associates (1965) demonstrated that both Dormin and Abscisin- II were chemically identical and given a common name Abscisic acid (ABA) because of its known effects on stimulating abscission.

Biosynthesis

Two pathways for the biosynthesis of ABA have been identified:

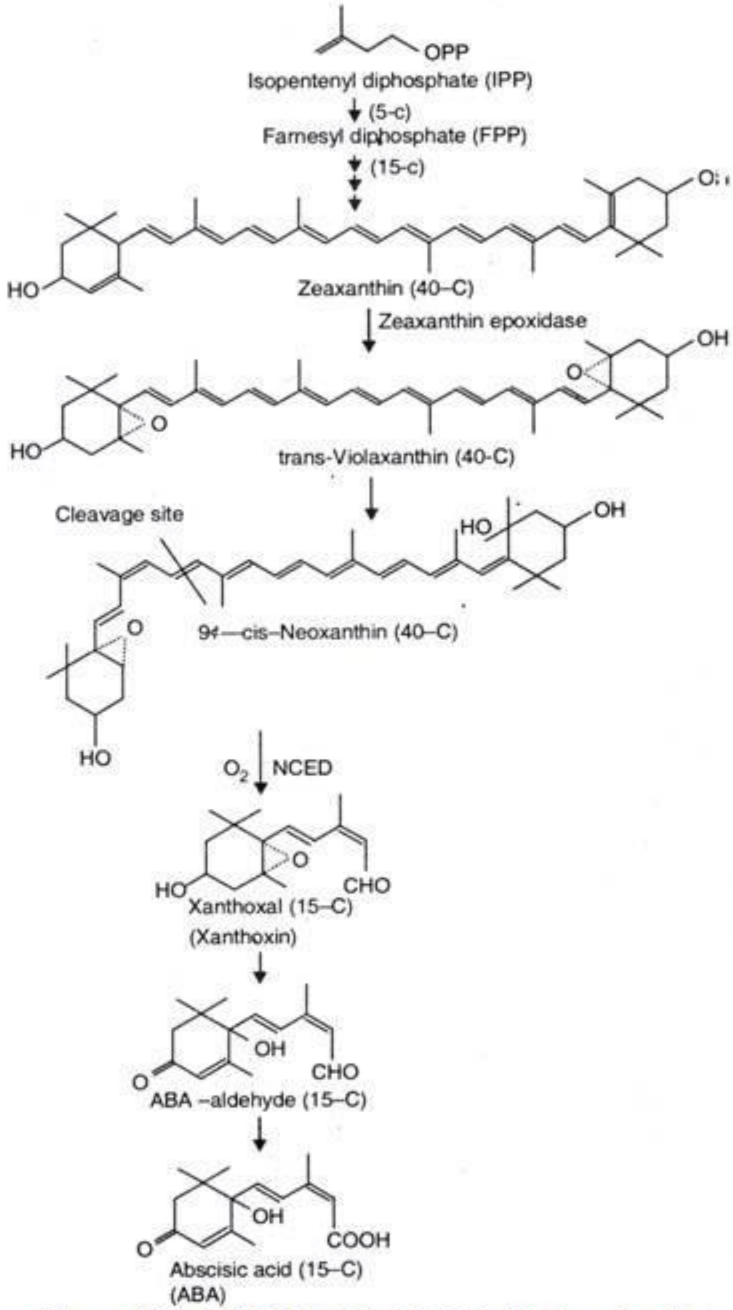
1) By direct synthesis from mevalonic acid: Direct synthesis of abscisic acid from mevalonic acid through farnesyl pyrophosphate has been demonstrated in many cases, especially in the water stressed tissues. The water stress increases Abscisic acid formation. The early reactions in the synthesis of abscisic acid are identical to those of gibberellins, sterols, carotenoids and other isoprenoid compounds.

Mevalonic acid→ Isopentenyl pyrophosphate→ Farnesyl pyrophosphate→ Abscisic acid

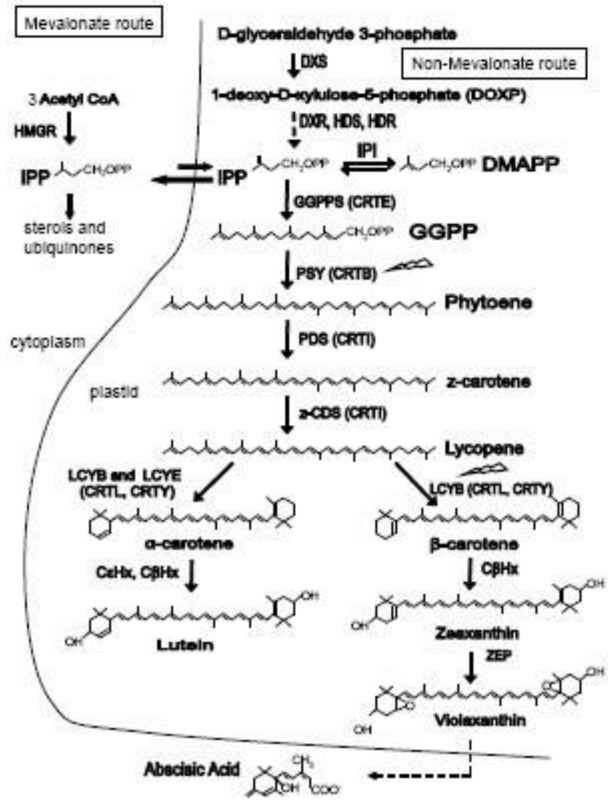
2) By indirect synthesis from the oxidation of carotenoids: Indirect synthesis of abscisic acid takes place by the oxidation of carotenoids or oxidized carotenoids (xanthophyll such as violaxanthin or neoxanthin). The xanthophyll, violaxanthin has been known to be the precursor of ABA. Violaxanthin in synthesized from zeaxantin (also a 40-C xanthophyll) in a reaction that is catalyzed by the enzyme zeaxanthin epoxidase (ZEP).

Violaxanthin is converted into 9' –cis-neoxanthin which 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 apoaldehyde).

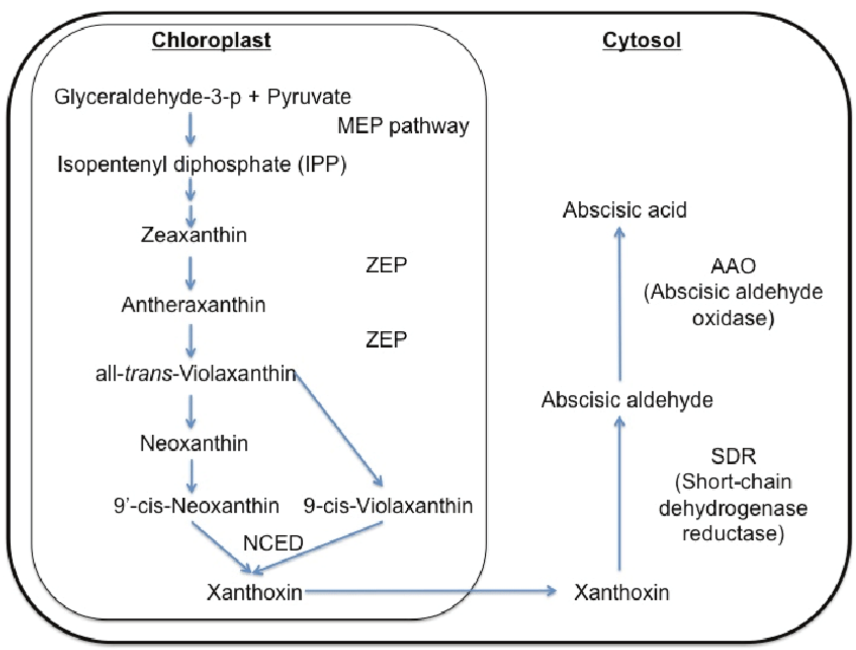
Xanthoxal (xanthoxin) is finally converted into ABA in cytosol via two oxidation steps catalysed by the enzymes aldehyde oxidases involving abscisyl aldehyde (and/or possibly xanthoxic acid) as intermediates. The enzymes aldehyde oxidases require Mo as cofactor. The initial steps of ABA biosynthesis take place in chloroplasts or other plastids while final steps occur in cytosol



Biosynthesis of Abscisic Acid in higher plants



Biosynthesis of ABA - mevalonate and non-mevalonate route



BIOSYNTHESIS OF ABSCISIC ACID

Physiological Role

1. Stomatal regulation: The most significant and best known effect of abscisic acid is its control of stomatal closing in water stress or drought plants. It inhibits K^+ uptake by guard cells and promotes the leakage of malic acid. It results reduction of osmotically active solutes so that the guard cells become flaccid and stomata get closed.

2 Seed and bud dormancy: ABA acts as growth inhibitor and induces bud dormancy in a variety of plants. It inhibits lateral growth of buds, as reported in Tomato. In general, it acts as an inhibitory chemical compound that affects bud growth, and seed and bud dormancy. In plant species from temperate parts of the world, it plays a role in bud and seed dormancy by inhibiting growth, but, as it is dissipated from seeds or buds, growth begins. In other plants, as ABA levels decrease, growth then commences as gibberellin levels increase. Without ABA, buds and seeds would start to grow during warm periods in winter and be killed when it froze again. Since ABA dissipates slowly from the tissues and its effects take time to be offset by other plant hormones, there is a delay in physiological pathways that provide some protection from premature growth. It accumulates within seeds during fruit maturation, preventing seed germination within the fruit, or seed germination before winter.

3. Seed development and germination: It has been observed that ABA accumulates in embryos of developing seeds, either it is synthesized de-novo or translocated from leaves. It inhibits formation of enzymes involved in germination process in the embryo and inhibits vivipary. Exogenous supply of ABA inhibits germination of most non-dormant seeds. As soon as it is removed by washing the seeds, the germination can take place which may be due to- inhibition of enzymes involved in germination process, inhibition of water uptake by germinating seeds, etc.

4. Senescence and Abscission: Many workers suggested ABA is an endogenous factor and involved in the senescence and abscission of leaves and other plant organs. Exogenous application of ABA induces primary yellowing in leaf tissues in a variety of species ranging from deciduous trees to herbaceous plants. ABA production increases in senescing leaves once the photosynthetic activity of the leaves decreases below the compensation point.

5. 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, translocate basipetally and stimulates positive geotropic response by acting as inhibitor.

6. 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.

7. Cambium activity: Abscisic acid stops mitosis in vascular cambium towards the approach of winter.

8. Role in water stress: Abscisic acid plays an important role in plants during water stress and drought conditions. It increases the tolerance of plants to different kinds of stress and is, therefore, called 'stress hormone'**.** It has been observed that the concentration of ABA increases in the leaves of plants facing such stresses. In plants under water stress, ABA plays a role in closing the stomata. Soon after plants are water-stressed and the roots are deficient in water, a signal moves up to the leaves, causing the formation of ABA precursors there, which then move to the roots. The roots then release ABA, which is translocated to the foliage through the vascular system and modulates the potassium and sodium uptake within the guard cells which then lose turgidity, results in closing the stomata.

9. Counteracts the effects of other hormones: Abscisic acid counteracts the stimulatory /inhibitory effects of other hormones: i) ABA inhibits cell growth promoted by IAA, ii) ABA inhibits amylase produced by seeds treated with gibberellins, iii) ABA promotes chlorosis, which is inhibited by cytokinin. This may be due to the fact that ABA is a Ca^{++} antagonist and its inhibition of the stimulatory effects of IAA and cytokinin may be due to its interference with Ca^{++} metabolism.

10. Some other effects are: Inhibits cell division and cell elongation, Induction of parthenocarpic development of Rose, Increase resistance of plants to cold, Inhibition of gibberellin mediated synthesis of amylase during germination of cereal grains, Inhibits fruit ripening, etc.

<u>Reference /Syllabus Books (For material & diagrams)</u>

1. A Text Book of Plant Physiology by H. S. Srivastava (Rastogi Publication)

2. A Text Book of Plant Physiology by S. K. Verma (S. Chand & Company Ltd.)

3. A Text Book of Plant Physiology by V. Verma (Emkay Publications).

4. Plant Physiology and Metabolism by Dr. H.N. Srivastava (Pradeep Publications)

5. Plant Physiology and Metabolism by Dr. Kamaljit & co-workers (S. Vinesh & Co.)

6. Plant Physiology and Metabolism by Dr. B.B. Arora (Modern Publishers)

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