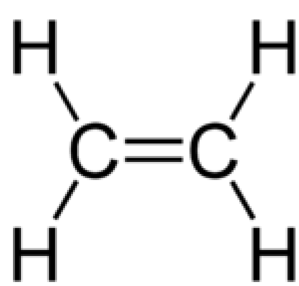
UNIT 5.1

Ethylene- Discovery, Biosynthesis and Physiological Role

Ethylene is the only plant growth regulator that occurs in the form of a gas. It is a volatile gas present in the atmosphere as a component of smoke and other industrial gases. It is produced by almost all parts of higher plants and usually present in minute quantity but causes marked effects. Thus it is not only a gaseous hydrocarbon but a plant metabolite. Like abscisic acid, ethylene is usually considered as inhibitory hormone.

It is a colorless flammable gas with a faint "sweet and musky" odour when pure and unsaturated hydrocarbon having double covalent bonds between and adjacent to carbon atoms. Being volatile in nature, ethylene gas is not used directly. Commercially, it is being used in the form of a substance ethephone (2- chloroethyl phosphonic acid) which after hydrolysis yields ethylene gas.



Structure of Ethylene

Discovery

Ethylene has been used since the ancient times. Egyptians gashed the figs in order to stimulate ripening (wounding stimulates ethylene production by plant tissues). The ancient Chinese would burn incense in closed rooms to enhance the ripening of pears. In 1864, it was discovered that gas leaks from street lights led to stunting of growth, twisting of plants, and abnormal thickening of stems. In 1874 it was discovered that smoke caused pineapple fields to bloom.

In 1901, a Russian scientist named Dimitry Neljubow observed that dark-grown pea seedlings growing in the laboratory exhibited symptoms like inhibition of stem elongation stem thickening and horizontal growth. When the plants were allowed to grow in fresh air, they regained their normal morphology and rate of growth. He identified it as ethylene, which was present in the laboratory air from coal gas, as a molecule causing the response. In 1912, A.F. Sievers and R.H. True demonstrated that the combustion gases from the kerosene stove were beneficial in the ripening of lemons. W.C. Crocker and L.I. Knight (1908, 1913) identified ethylene as the active constituent of both, illuminating gas and tobacco smoke. The first report that plant materials evolve ethylene came from H.H. Cousins, who observed that when oranges and banana were stored together during shipping, some gas was emanated from oranges which caused ripening of banana.

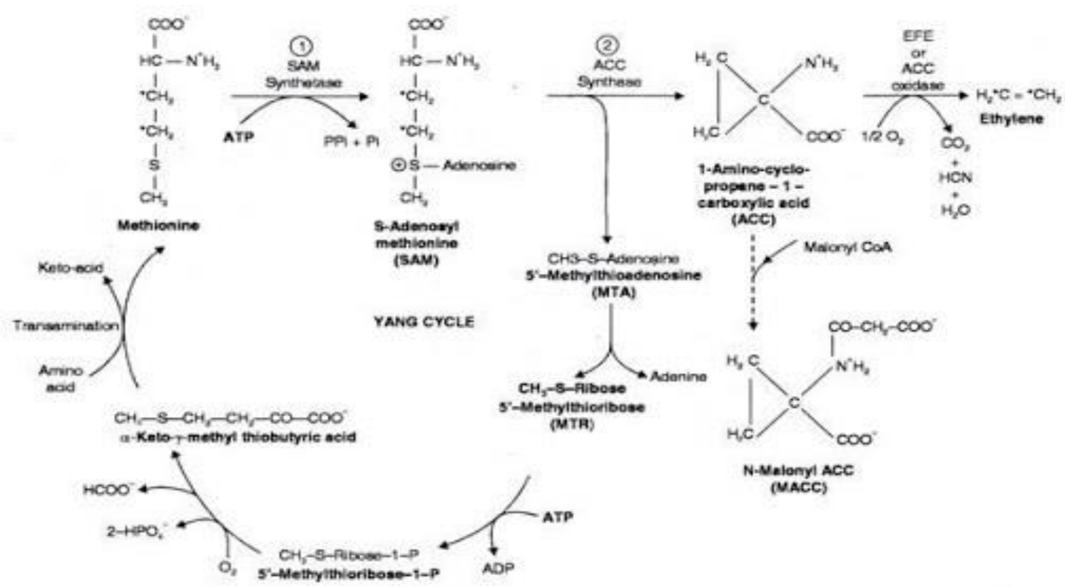
Sarah Doubt (1917) discovered that ethylene stimulated abscission. Farmers in Florida would commonly get their crops to ripen in sheds by lighting kerosene lamps, which was originally thought to induce ripening from the heat. In 1924, Frank E. Denny discovered that it was the molecule ethylene emitted by the kerosene lamps that induced the ripening. In 1932, O.H. Elmer reported that the sprouting of potatoes could be inhibited by keeping them in close proximity of mature apples or pears. R. Gane (1934) provided a chemical proof that ethylene was produced by ripe apples.

Since then it has been shown that ethylene is produced from essentially all parts of higher plants. During the life of the plant, ethylene production is induced during certain stages of growth such as germination, ripening of fruits, abscission of leaves and senescence of flowers. Ethylene production can also be induced by a variety of external aspects such as mechanical wounding, environmental stresses and certain chemicals including auxin and other plant growth regulators.

Biosynthesis

The pathway for ethylene biosynthesis, also called Yang Cycle, is given by Sgang Fa Yang in 1980 The pathway for biosynthesis of ethylene from methionine is as:

The sulphur containing aminoacid, **methionine** is activated with ATP and is converted to **S-adenosyl methionone** to (SAM) and pyrophosphate is liberated. This reaction is catalyzed by the enzyme SAM synthetase(ATP- Methionine S- Adenosyl transferase). In **S- adenosyl methionone**, the sulfur atom of methionine is linked to the C-5 of the ribose moiety in adenosine. In many cases, solenomenthionine has been found to be the better substrate for ethylene biosynthesis than methionine. The enzyme SAM synthetase has a higher affinity for solenomethionine than for methionine. The next step in the biosynthesis of ethylene is the **conversion of SAM to 1-amino cyclopropane carboxylic acid** (ACC), which is catalyzed by the enzyme ACC synthase (ACS). This step is believed to be the rate limiting step in ethylene production and any factor influencing the activity of ACC synthase influences ethylene production. The final step in the biosynthesis of ethylene is oxidative cleavage of **1-amino cyclopropane carboxylic acid** (ACC) to form **ethylene, CO_2** and **HCN** by the enzyme ACC-oxidase (ACO), formerly known as the ethylene forming enzyme (EFE). HCN is ultimately converted to formic acid and ammonia. This reaction requires O_2 and is activated by light.



Ethylene Biosynthesis Pathway in Higher Plants

<u>Physiological Role</u>

1. Fruit Ripening: Acceleration of fruit ripening was the first discovered effect of ethylene and due to this character it is also called ripening hormone. The stimulation of fruit ripening by ethylene is a consequence of many ongoing processes such as – i) breakdown of chlorophyll, ii) fruit softening due to breakdown of cell walls by cellulose and pectinase and iii) conversion of starches to sugars. Fruit ripening can be climacteric or non-climacteric and both types react differently with exogenous application of ethylene but this process is well marked in climacteric fruits Climacteric fruits (e.g. apple, apricot, avocado, banana, blueberry, fig, mango, kiwi , tomato and papaya) generate large amount of ethylene and show a marked increase in respiration as ripening proceeds. This increase in respiration is called climacteric and fruits that show this are known as climacteric fruits. So, the increase in ripening (climacteric) initiates just after an enormous increase in ethylene production. But in non-climacteric fruits (cherry, cucumber, grape, lemon, pineapple, strawberry, sweet orange, etc.) ethylene treatment does not cause respiration climacteric and additional ethylene production and the rate of ripening process remains unaffected.

2. Seed germination: Ethylene plays a significant role in breaking seed dormancy and inducing seed germination in plants like ground nut, wheat, lettuce and cocklebur. It also causes the increased extension growth of the seedlings in cocklebur (*Xanthium strumarium*).The maximum germination however is obtained at about 40-50ppm ethylene. During germination,

3. Flower inhibition and sex expression: In most of the plants, flowering is inhibited by ethylene, although it is known to promote flowering in mango and pineapple. Inhibition of flowering by ethylene is controlled by the photoperiod and has been suggested that its application during the dark period produces some flower inhibiting. Ethylene also changes sex expression in unisexual plants. It promotes female flower production particularly in some cucurbits by suppressing the number of male flowers thus induces male sterility.

4. Epinastic Responses: Ethylene induces epinasty in leaves in flooded /water logged roots. These roots create anaerobic conditions and forms aminocyclopropane-1-carboxylic acid which is transported up by the xylem to the leaf where it is converted to ethylene in the presence of oxygen and induce epinasty i.e. the upper side of the petiole of the leaf grows faster than the lower side and the leaf curves downwards, which perhaps help the plant to lose water. Ethylene causes epinasty in tomato, potato, pea and sunflower.

5. Growth inhibition and morphogenetic effect: Ethylene inhibits the elongation growth of stems in most dicots by affecting cell growth and shape but it enhances radial growth. When a growing shoot hits an obstacle while underground, ethylene production greatly increases, preventing cell elongation and causing the stem to swell. The resulting thicker stem can exert more pressure against the object impeding its path to the surface. If the shoot does not reach the surface and the ethylene stimulus becomes prolonged, it affects the stem's natural geotropic response, which is to grow upright, allowing it to grow around an object. It has been suggested that ethylene affects stem diameter and height. When stems of trees are subjected to wind, causing lateral stress, greater ethylene production occurs, resulting in thicker and sturdy tree trunks and branches.

6. Acceleration of senescence and abscission: Ethylene promotes/ accelerates senescence and abscission of plant parts, both natural and induced. It accelerates senescence of leaves, flowers and fruits as endogenous ethylene increases during senescence which reduces or degrades chlorophyll content. Ethylene also induces abscission of leaves (eg. bean, orange, rubber. mulberry, etc.), flowers (e.g. begonia, tobacco, apple, tomato, etc.) and fruits (eg. apple, orange, avocado, prune, etc.). When applied exogenously (0.05ppm) ethylene causes 100% abscission of young fruits and floral buds of cotton plants within two days.

7. Some other effects/roles are: regulates the growth of cell wall, stimulates the formation of new roots, induces the growth of adventitious roots during flooding, induces root hair growth, induces plumular hook formation, induces de nova synthesis of peroxidase, etc.

In conclusion, one or the other plant growth regulator influences every phase of growth or development in plants. These roles could be individualistic or synergistic; promoting or inhibiting.

Additionally, more than one plant growth regulator, along with extrinsic factors, plays critical role in plant growth and development.

What are plant growth regulators?

Plant Growth Regulators are defined as small, simple chemicals produced naturally by **plants** to regulate their **growth** and development.

What are the 5 plant growth regulators?

There are **five** types of **plant** hormones/plant growth regulators namely, **auxin**, **gibberellins** (GAs), **cytokinins**, **abscisic acid** (ABA) and **ethylene**.

<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)