ETHYLENE IN PLANT BIOLOGY

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13

Mechanism for Ethylene Synthesis and Homeostasis in Plants: Current Updates

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13.1 Introduction

Ethylene is a gaseous compound with an unsaturated hydrocarbon having the chemical formula $H_2C{=}CH_2$. Its International Union of Pure and Applied Chemistry (IUPAC) name is ethene. It is a natural compound synthesized by plants for various functions. In plants, ethylene (ET) behaves like a plant hormone and is responsible for several vital functions. In plants, many hormones are synthesized, such as auxins, gibberellins, abscisic acid (ABA), cytokinins, jasmonic acid, and brassinosteroids; but ET is the only gaseous hormone produced by all plants (Salisbury and Ross 1992; Raven et al. 1992; Arteca 1996). In the early twentieth century, harmful effects of the gas were observed on pea seedlings (Kende 1998). The active form of ET was first analyzed by Neljubow in 1901. However, Gane (1934) reported its synthesis in plants.

ET is an unsaturated organic compound responsible for the normal growth and development of plants. Kende (1998)found that ET gas, due to its unsaturated hydrocarbon nature, could easily diffuse through cell membranes, followed by quick signal transduction within the system. ET regulates proper plant growth through its effects on functions such as seed germination, abscission, fruit ripening, triple response, epinasty, stress tolerance, sex determination, senescence, etc. (Abeles et al. 1992). Due to its extensive role in plant development and growth, it is important to understand the biosynthesis and homeostasis of ET in plants. New area of ET studies are ET activities and concentration in plants.

ET is a multifunctional plant hormone involved in both plant development and senescence. It controls leaves, flowers, fruit development, and senescence based on its concentration and activity (Konings and Jackson 1979; Khan 2005; Pierik et al. 2006). Iqbal et al. (2017) described the role of ET in controlling genetic networks with one or more other plant hormones to integrate signals and allow plant growth at different stages. ET controls plant growth and development based on its concentration and the stages where it is involved directly or indirectly through crosstalk (Iqbal et al. 2017). It provides a suitable

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15

Ethylene and Metabolic Reprogramming under Abiotic Stresses

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15.1 Introduction

Ethylene (ET) is a gaseous plant hormone (Abeles et al. 1992) involved in plant growth functions. It is an endogenous plant hormone synthesized by almost all plants. It has many functions in plants, such as fruit ripening, senescence, abscission, rooting response, and regulating flowering. It is also involved in changing the sex of developing flowers, epinasty (the downward curvature of leaves), etc. ET was first demonstrated by Dimitry Nikolyevich Nelijubow in 1886. He said that plants adapt themselves to different environmental conditions by responding with ET. In 1934, the first evidence for the biosynthesis of ET in plants was provided by Richard Gane (Kende 1998). Under abiotic stress, ET and abscisic acid (ABA) play a crucial role in maintaining plants' development and growth. It helps plants by causing a triple response that occurs in given environmental conditions.

Stresses are environmental circumstances that hinder the growth of plants. As we all know, plants encounter different stresses and respond accordingly. Stress may be abiotic or biotic. Abiotic stresses include physical conditions such as high temperature, very low temperature, excessive wind, drought conditions, waterlogging, extreme sunlight, and humidity. Or the stresses may be in the form of chemical conditions like soil fertility (excess soil salinity) or deficient essential nutrients (N, P, S, Cl, etc.). Biotic stresses are caused by living organisms: insects, pathogen, and phototoxic compounds from nearby plant species can affect plants. These stresses can be altered by gene expression via alternate pathways or the metabolism occurs in plants to trigger such stresses. Drought stress induces injury such as loss of membrane integrity in plants, and chemical stress like P deficiency causes dark green patches or coloration of the leaves with patches with dead tissues. So it is essential to know and understand the proper response or metabolic changes to reprogram stress conditions in plants. Anderson et al. (2004) mentioned that under stress conditions, plantsrespond accordingly and survive (Figure 15.1). In this chapter, we compile the current understanding of metabolic changes under conditions such as flooding and epinasty

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19

Ethylene and Nitric Oxide Crosstalk in Plants under Abiotic Stress

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19.1 Introduction

Auxins, gibberellins (GAs), cytokinins (CKs), ethylene (ET), abscisic acid (ABA), jasmonates (JAs), salicylic acid (SA), strigolactones, and brassinosteroids (BRs) are the major hormones produced by plants (Bari and Jones 2009). Of these ET, SA, JAs, and ABA are recognized as playing key roles in intervening in plant protection response against abiotic and biotic stresses (Nakashima and Yamaguchi-Shinozaki 2013). The defense responses initiated in plants in response to stresses are not only based on the individual contributions of each hormone; rather, they are regulated by the kind of positive or negative crosstalk among the signaling pathways of hormones.

ET (C_2H_4) controls several phases of growth and development in plants (Schaller 2012). It is usually connected with the regulation of cell volume, frequently restricting cell elongation, and is most commonly considered an "aging" hormone, as it accelerates and is essential for processes such as senescence, epinasty, fruit ripening, flowering, sex expression, and abscission (Pierik et al. 2006). It also regulates the development of leaves, flowers, and fruits (Iqbal et al. 2012). Depending on the application timing, concentration, and plant species, ET reduces or enhances growth and senescence.

The signaling molecule nitric oxide (NO) is identified as having a regulatory role in a variety of plant responses such as cell proliferation (Ribeiro et al. 1999), stomatal closure (Neill et al. 2002), flowering and fertilization (Domingos et al. 2015), biotic and abiotic stresses (Mostofa et al. 2015), senescence (Corpas et al. 2004), ET emission (Leshem and Haramaty 1996), and programmed cell death (Pedroso et al. 2000). NO in plants has also been shown to arbitrate in processes mediated by hormones such as SA, ABA, auxins,

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