Chapter

Types and Function of Phytohormone and Their Role in Stress

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Abstract

Plants require sunlight, water, oxygen, and minerals to grow and flourish. Along with the external environments, plant cell functioning is regulated by chemicals and plant hormones, also known as phytohormones or plant growth regulators (PGRs). Plant hormones are chemical substances, like signalling molecules found in plants at extremely low concentrations. Hormones such as auxins, cytokinins, gibberellins, ethylene, abscisic acid, jasmonic acid; salicylic acid, brassinosteroids, and strigolactones are the classes of plant hormones playing vital role in plant. All these hormones are produced in practically every region of the plant and are distributed throughout the plant. Hormones, as well as external variables, play a vital role in processes such as vernalisation, phototropism, seed germination, and dormancy, because these hormones are responsible for translating the external signal into adaptive growth and developmental changes, that help plant to survive better. They also evolved as cellular signal molecules with important roles in the modulation of immunological responses to bacteria, insect herbivores, and beneficial microorganisms. Hence, plant hormones govern a variety of biological activities ranging from growth and development to biotic and abiotic responses. This chapter will focus on various classes of plant hormones and their role in growth and development along with the stress.

Keywords: plant hormone, signalling molecules, growth and development, abiotic and biotic stress

1. Introduction

1.1 The meaning of a plant hormone

Plants need sunlight, water, oxygen, minerals for their growth and development. These are. Apart from external factors there are some intrinsic factors that regulate the growth and development of plants [1]. These are called plant hormones or "Phytohormones". The term "hormone" was originally used narrowly to refer to secretory substances generated by particular organs, glands, tissues, or cells in animals that were transported by veins (or other comparable tissues) to more or less specific tissues and had some effect on their metabolism [2]. However, the terminology is now always used to refer to the mobile signals of living creatures and is frequently used with a heading to indicate the type of living things, such as animal hormones, plant hormones, insect hormones, etc. Every living species has hormones that are frequently exclusive to that species and reflect the traits of its biological occurrences. The peculiar growth phenomenon known as developmental plasticity, in which a plant continuously forms new organs and tissues throughout its life cycle, can be attributed, at least in part, to the features of plant hormones [3]. Plant hormones are a group of organic, naturally occurring chemicals that, when present in small amounts, affect physiological functions. Growth, differentiation, and development are the primary processes impacted, while other processes, such stomatal movement, may also be impacted. Although the term "phytohormones" is not commonly used, plant hormones have also been referred to as such [4].

- Plant hormones are chemical compounds present in very low concentration in plants. They are derivatives of indole (auxins), terpenes (Gibberellins), adenine (Cytokinins), carotenoids (Abscisic acid) and gases (Ethylene). These hormones are produced in almost all parts of the plant and are transmitted to various parts of the plant. They may act synergistically or individually. Roles of different hormones can be complementary or antagonistic. Hormones play an important role in the processes like vernalisation, phototropism, seed germination, dormancy etc. along with extrinsic factors.

- Two types of plant hormone Synthetic and Natural. Synthetic plant hormones are exogenously applied for controlled crop production Charles Darwin first observed the phototropism in the coleoptiles of canary grass and F.W. Went first isolated auxin from the coleoptiles of oat seedlings. Plant hormone (phytohormones) is chemicals produced by plants that regulate their growth, development, reproductive processes, longevity, and even death.

Plant hormones control every phase of the life cycle of the plant. In general, more than one hormone influences plant biological activity, therefore the biological phenomena frequently represents the combined interactions of multiple distinct hormones [5]. When plants confront biotic and abiotic pressures, they can only survive by altering various biological processes, unlike animals that may flee from harsh situations. In these circumstances, plant hormones also work together to alter biological reactions for the establishment and maintenance of plant stress tolerance. Transducing extracellular or intracellular signals into cellular responses is a process known as signal transduction. The processes of signal transduction are involved in hormones functioning. Hormones are compounds that function at low concentrations that circulate through some or all living creatures to signal and regulate the response, growth, and development of those organisms [6].

2. Class of phytohormone

Plant hormones (phytohormones) are chemicals produced by plants that regulate their growth, development, reproductive processes, longevity, and even death. These small molecules are derived from secondary metabolism and are responsible for the adaptation of plants to environmental stimuli. Plants are subjected to an ever changing environment and require these phytohormones for appropriate responses. A single phytohormone can regulate many cellular and developmental processes, while at the same time multiple hormones often influence a single process [7].

Auxin, gibberellins, cytokinins, ethylene and abscisic acid are the five primary phytohormone. Other phytohormone that influences plant physiological processes include brassinosteroids, salicylates, jasmonates, strigolactones, etc (**Table 1**) [8].

2.1 Auxin

2.1.1 Introduction

The first growth hormone to be identified was auxin. They were discovered due to the observations of Charles Darwin and his son, Francis Darwin. The coleoptile (protective sheath) of canary grass develops and bends in the direction of the light source, as seen by the Darwin's. This is known as "phototropism." Additionally, their research demonstrated that the coleoptile tip was the location where the bending occurred. As a result, F. W. Went was able to isolate the first auxin from the coleoptile tip of oat seedlings [9]. The apical meristem of shoots, young leaves, and seeds is where auxin is mostly produced. From the point of production, auxin moves downward in a unidirectional or polar manner. Auxin concentration gradient produced by polar transit drives specific responses. The plasma membrane's auxin-specific transport proteins regulate how auxin leaves the call. Plant hormones work through signal transduction, triggering several cellular responses. Auxin attaches to receptors that are related to enzymes, which encourages reaction catalysis. The repressor protein for certain genes (the auxin response gene) attaches to ubiquitin when auxin binds to a receptor. This causes the repressor protein to be degraded, and the transcription of auxin response genes proceeds, promoting cellular growth and development [10].

2.1.2 Function

Auxin, plays a crucial role in regulating growth and development. Indole-3-Acetic Acid (IAA), Indole-3-Butyric Acid (IBA), and 4-chloro-indole-3-acetic acid are all members of this hormone family that are found in nature. Auxin levels vary dramatically within the plant body and throughout the life cycle of the plant, forming complex gradients that appear to be a central component of its regulatory activity for plant development. In order to control auxin levels in particular tissues in response to shifting environmental and developmental factors, plants have evolved complex networks with adaptive flexibility as well as genetic and biochemical redundancy [11]. Indole-3-acetic acid (IAA) is the main auxin in most plants (natural auxin) 2, 4-Dichlorophenoxy Acetic acid, Indole-3-Propionic Acid, alpha- Naphthalene Acetic Acid are synthetic auxins.

2.2 Gibberellins

2.2.1 Introduction

Gibberellins are plant growth regulators that control growth and have an impact on a variety of developmental processes, including stem elongation, germination, blooming, enzyme induction, and so on. The most pronounced effect of gibberellins on plant

Hormone	Where produced or found in plant	Major function
Auxin (IAA)	Shoot apical meristems and young leaves are the primary site of auxin synthesis, root apical meristem also produce auxin, also the root depends on shoot for much of its auxin .developing seeds and fruits contain high levels of auxin, but it is unclear whether it is newly synthesised or transports from maternal tissues	Stimulate stem elongation (low concentration only); promotes the formation of lateral and adventitious roots; regulates development of fruit: enhances apical dominances; functions in phototropism and gravitropism; promotes vascular differentiation; retards leaf abscission.
Cytokinins	These are synthesised primarily in roots and transported to other organs, although there are many minor sites of production as well.	Regulate cell division in shoots and roots; modify apical dominance and promote lateral bud growth; promote movement of nutrients into sink tissues; stimulate seed germination; delay leaf senescence.
Gibberellins	Meristems of apical bud and roots, young leaves, and developing seed are the primary sites of production.	Stimulate stem elongations, pollen development pollen tube growth, fruit growth, and seed development and germination; regulate sex determination and the transition from juvenile to adult phases.
Brassinosteroids	These compounds are present in all plant tissues, although different intermediates predominate in different organs. Internally produced brassinosteroids act near the site of synthesis.	Promote cell expansion and cell division in shoots; promote root growth at high concentrations; inhibit root growth at high concentration; promote xylem differentiation and inhibit phloem differentiation; promote seed germination and pollen tube elongation.
Abscisic acid (ABA)	Almost all plant cells have the ability to synthesise abscisic acid, and its presence has been detected in every major organ and living tissue; may be transported in the phloem or xylem.	Inhibits growth; promotes stomatal closure during drought stress; promotes seed dormancy and inhibits early germination; promotes leaf senescence; promotes desiccation tolerance.
Strigolactones	These carotenoid-derived hormones and extracellular signals are produced in roots in response to low phosphate conditions or high auxin flow from the shoot.	Promote seed germination, control of apical dominance, and the attraction of mycorrhizal fungi to the root.
Ethylene	This gaseous hormone can be produced by most parts of the plant. It is produced in high concentrations during senescence, leaf abscission, and the ripening of some types of fruits. Synthesis is also stimulated by wounding and stress.	Promotes ripening of many types of fruit, leaf abscission, and the triple response in seedling (inhibition of stem elongation, promotion of lateral expansion, and horizontal growth); enhances the rate of senescence; promotes root and root hair formation; promotes flowering in the pineapple family.

Table 1.
Summary of various phytohormone with their major functions.

development is the elongation of the stem [12]. When it is administered to a shrub at low concentration, the stem begins to grow. Different dwarf kinds' genetic restrictions are overcome via Gibberellins. More than 70 gibberellins have been isolated. The numbers are GA1, GA2, GA3, and so forth. The most extensively researched plant growth regulator is GA3, or gibberellic acid. GAs are a family of plant hormones with about 135 members that are classified as diterpenoids with a gibberellin basic structure [13].

2.2.2 Function of gibberellins

- **Seed germination.** In the absence of sunshine, some seeds that are light-sensitive, like lettuce and tobacco, germinate poorly. If the seeds are placed in the sunshine, germination starts right away. The need for light can be met if the seeds are given a gibberellic acid treatment.

- **Dormancy of buds.** Autumn-formed buds dormant till the spring. By administering gibberellin to them, you can break them out of their dormant stage.

- **Root growth.** Gibberellins hardly have any impact on root development. A few plants, nevertheless, may experience modest growth inhibition at a greater dose.

2.3 Cytokinins

2.3.1 Introduction

Adenine derivatives known as cytokinin have the capacity to stimulate cell proliferation in tissue culture [14]. The most common natural occurrence of cytokinin in plants is zeatin. Cytokinin is transported via the xylem from roots to shoots. Exogenous injections of Cytokinins stimulate cell division in tissue culture when auxin is present. Cytokinins promote shoot initiation in moss; Cytokinins induce bud formation Growth of lateral buds. Cytokinin applications, or the increase in Cytokinin levels in transgenic plants with genes for enhanced Cytokinin synthesis, can cause the release of lateral buds from apical dominance [15].

Natural Example of plant hormone Cytokinins are isopentenyl adenine and Zeatin (corn kernels, coconut milk) while Synthetic: Benzyladenine, Kinetin, thidiazuron, and diphenylurea [16].

2.3.2 Functions of plant hormone cytokinins

- This promotes lateral and adventitious shoot growth and is used in culture to initiate shoot production.

- Assists in resolving auxin-induced apical dominance.

- Stimulate the production of chloroplast in the leaves.

- Promoting the mobilisation of nutrients and slowing leaf senescence.

Cytokinin helps in encouraging plant growth and cell division. Utilised by farmers to boost crop output even under drought-like circumstances, it has a positive effect on cotton seedlings by 5–10% seedling emergence [17]. By promoting resistance to certain disease-causing bacteria, plays a significant part in the pathogenesis of plants.

2.3.3 Cytokinin transport

In the xylem and phloem, cytokinins are moved from roots to shoots and the other way around. By conveying information about nutrient availability, for instance, transported cytokinins may play a part in coordinating root and shoot growth. To enable effective mobilisation and tailored translocation of cytokinins, many cellular importers and exporters are necessary, although little is understood about cytokinin transporters. According to transport studies, cytokinins are transported through a widespread H + -coupled high-affinity purine transport pathway [18].

2.4 Ethylene

2.4.1 Introduction

The important hormone ethylene controls and mediates intricate cycles in plants that affect their growth and development as well as their ability to survive throughout their life cycle. The capacity of ethylene to ripen fruits and cause senescence is its primary use and area of scientific study. The potential to accelerate the ripening of fruits where ethylene is the primary hormone, such as tomato and banana fruits, has been the main focus for food biotechnologists. By regulating the manufacture of the ethylene hormone, food biotechnologists hope to be able to control the ripening of fruit [19].

We must first comprehend how ethylene is secreted in the tissues of a plant in order to comprehend its function. Two stages make up the metabolic process that produces ethylene [20].

It begins with a substance called SAM (S-adenosyl-L-methionine). The enzyme ACS aids in the conversion of SAM into ACC (ACC synthase). ACO is an enzyme that converts ACC to ethylene (ACC oxidase) [21].

It is important to realise that the enzymes ACS and ACO are both released by various gene coding families in synchrony with one another when conditions like drought, flood, wound, exerting pressure from the outside, and pathogen assault occur [22].

2.4.2 Functions of ethylene

In plants, ethylene is used for a variety of purposes. Seed germination, shoot and root growth, root development, abscission of leaves and fruits, the creation of adventitious roots, senescence of leaves and flowers, and sex determination are a few of the crucial tasks that ethylene performs. For instance, in plant tissue, ethylene stimulates the development of air-filled cavities known as aerenchym tissues during floods, which aids in the oxygenation of plants. However, the ripening of climacteric fruits, such as peaches, bananas, apples, and tomatoes, is ethylene's most significant role. For instance, putting a ripe banana in a bag of immature avocados would speed up the avocados' ripening process. The build-up of ethylene in the bag is to blame for this.

In summary Ethylene's important uses are the following:

- The generation of female flowers in a male plant.
- Producing root growth to enhance the capability of the root to absorb more water and minerals.
- Evoking a phenomenon called epinasty. Epinasty is a complex behaviour seen in plants when the roots are flooded. During floods, the top layer of the leaves

grows more than the bottom ones. This induces the leaves to drop and rather than being horizontal the leaves become more vertical. This is specially induced by ethylene when it is converted to ACC and transported from the xylem to the tissues of leaves on the upper part.

- Ethylene promotes negative geotropism, where it ensures that the growth of the roots is towards the ground. Hence, more area of roots in the soil indicates easy absorption of minerals from the soil.
- The sex of a flower can be determined.
- Influences seed germination.
- Has a great role in the initiation of root growth and pollination.
- The flowering of pineapple flowers can be hastened by ethylene.
- It breaks the dormancy of buds, seeds and storage organs of the plants.
- It increases the dormancy of lateral buds and improves apical dominance [23].

2.5 Abscisic acid

2.5.1 Introduction

Abscisic acid is the plant stress hormone (ABA). It inhibits plant development and regulates abscission and dormancy. The naturally occurring Abscisic acid is dextrorotatory (+), but commercially available synthesised ABA is a racemic combination. ABA is transported by the xylem, phloem, and parenchyma cells [24].

Discovery of ABA took place between 1950 and 1960, scientists had a hunch that when a growth stimulating endogenous hormones are present in the plant cell, growth inhibiting hormones which causes the senescence or abscission of fruits must be governed by other hormones namely abscisic acid(ABA). ABA does not cause abscission, they just inhibit growth [25]. Violaxanthin and neoxanthin are Xanthophylls that are used to synthesise ABA. Epoxidation, or the presence of epoxy-carotenoids, is required for ABA production. The synthesis however initiates from IPP forming GGPP further leads to the formation of Zeaxanthin produces violaxanthin. Violaxanthin forms cis—neoxanthin followed by cis—xanthin produces ABA Aldehyde leads to ABA [26]. Synthesis occurs in mature leaves and stems, as well as developing fruits, seeds.

Abscisic acid is referred to as a stress hormone since its production is promoted by environmental challenges such as drought and water logging. It is crucial in the tolerance of abiotic stress. ABA is important in a variety of developmental and physiological processes, including:

- ABA causes stomata to close when excessive salinity, water stress, and lowers water loss through transpiration. To stimulate stomatal closure, ABA interacts with other phytohormones such as jasmonates, nitric oxide, and signalling molecules.

- ABA causes seed dormancy, allowing seeds to tolerate desiccation and other unfavourable growth factors. Seeds can be stored for an extended period of time.

- ABA is essential for root development and modification under nitrogen deprivation and drought. It controls gene expression, which is necessary for root development, maintenance and water absorption.

- ABA affects protein-encoding genes as well as lipid and storage protein production.

- ABA is required for the signal transduction pathway during the stress response.

- Abscisic acid participates in the production of dehydrins, osmoprotectants, and protective proteins.

- By modulating stress-responsive genes, ABA promotes long-term development [27].

2.6 Jasmonic acid

2.6.1 Introduction

Jasmonic acid (JA) is an organic compound found in several plants including jasmine. The molecule is a member of the jasmonate class of plant hormones. It is biosynthesized from linolenic acid by the octadecanoid pathway. It was first isolated in 1957 as the methyl ester of jasmonic acid by the Swiss chemist Edouard Demole and his colleagues.

Jasmonates are represented by jasmonic acid (JA) and its methyl ester. The plant hormone jasmonic acid (JA) and its derivative (jasmonoyl isoleucine: JA-Ile) are signalling molecules involved in the control of cellular defence and development in plants. Jasmonic acid plays a vital role in the various plant developmental processes including flowering, fruiting, senescence and secondary metabolism. These are known to be critically important in plant defence and abiotic stress response. Jasmonic acid stimulates the antioxidant system, induces amino acid and soluble sugar accumulation, and modulates stomatal opening and closing during abiotic stress [28].

2.6.2 Function

1. Jasminates play an important role in plant defence, where they induce the synthesis of proteinase inhibitors which deter insect feeding, and, in this regard, act as intermediates in the response pathway induced by the peptide system in.

2. Jamonates inhibit many plant processes such as growth and seed germination.

3. They promote senescence, abscission, tuber formation, fruit ripening, pigment formation and tendril coiling.

4. JA is essential for male reproductive development of Arabidopsis. The role in other species remains to be determined [29].

2.7 Salicylic acid (SA)

2.7.1 Introduction

Salicylic acid (SA) is a member of the salicylates group of chemicals, which are phenolic compounds generated by plants and have an aromatic ring and a hydroxyl group. Salicylates were used as pain relievers for thousands of years before they were chemically identified.

Salicylic acid and its derivatives, as one of the plant hormones generated naturally, belong to the phenolic acid group and consist of a ring connected to the hydroxyl and carboxyl groups, with cinnamic acid as the starting component. It is mostly produced in cytoplasmic cells of the plant. Symbolised by the symbol SA called chemical orthohydroxybenzoic acid chemical formula is $C7H6O3$ [30].

2.7.2 Salicylic acid's chemical composition

2.7.2.1 Function

Many physiological and biochemical processes, including photosynthesis, ion absorption, membrane permeability, enzyme activity, flowering, heat generation, and plant growth and development, are influenced by Salicylic acid.

Its effects include, among others, the inhibition of root growth, variation in chlorophyll content, carotenoids, and xanthophylls, increased water use efficiency, improved nitrogen uptake by some species, inhibition of ethylene generation, alteration of plant nutrition, inhibition of the absorption of some substances, and regulation of flowering.

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2.8 Brassinosteroids

2.8.1 Introduction

Brasinosteroids, the sixth plant hormone after auxin, gibberellins, cytokinin, abscisic acid, and ethylene, are structurally similar to steroid hormones found in animals. Brassinosteroids are important plant hormones that function similarly to animal hormones in a variety of biological processes, such as cell division, cell elongation, root development, photomorphogenesis, stomatal and vascular differentiation, seed germination, immunity, and reproduction. Brassinosteroids are also involved in regulating the metabolism of plant oxidation radicals, ethylene synthesis and root gravitropic response, and have a role in mediating plant responses to stress, such as freezing, drought, salinity, disease, heat and nutrient deficiency. Depending on growth state, this subfamily of hormones controls a wide variety of activities in plant development and responses to environmental challenges. Analogs of these hormones have been demonstrated to significantly boost grain production.

There are at least 70 polyhydroxylated sterols in the class of Brasinosteroids. These substances are similar in structure to animal steroid hormones that control the function of complex genes is influenced by the expression of several genes metabolic processes, which help to control cell division, differentiation, help in morphogenesis regulation, and regulate certain plant development stages, including blooming and cell expansion [32].

2.8.2 Function

Agriculture is where brassinosteroid is initially used. Therefore, during both abiotic and biotic stress, such as salt and drought stress, extremes in temperature, and disease assault, brassinosteroid mediates in plants. By applying them exogenously, they can be utilised to regulate the time of blooming in some plant species. Brassinosteroid deficiency has been linked to dwarfing phenotypes, short petioles, delayed blooming, and decreased fertility in plants [33].

1. Cell Division, possibly by increasing transcription of the gene encoding cyclinD3 which regulates a step in the cell cycle

2. Cell elongation, where BRs promote the transcription of genes encoding xyloglucanases and expansins and promote wall loosening. This leads to stem elongation.

3. Vascular differentiation.

4. BRs are needed for fertility: BR mutants have reduced fertility and delayed senescence probably as a consequence of the delayed fertility.

5. Inhibition of root growth and development.

6. Promotion of ethylene biosynthesis and epinasty [34].

2.9 Strigolactones

2.9.1 Introduction

Strigolactones are a class of carotenoid-derived plant hormones that are found in a wide variety of plant species, ranging from mosses to higher plants. They are crucial for the stimulation and branching of parasitic plants as well as the symbiosis and growth of arbuscular mycorrhizal fungus in soil. In 1966, cotton root exudate was the source of the first Strigolactones to be identified, called Strigol. Its name was connected to the Striga plant genus, a typical parasite of this crop. The creation of adventitious and lateral roots, as well as the induction of secondary growth, acceleration of leaf senescence, promotion of internode growth, and root elongation are all regulated by Strigolactones [35].

2.9.2 Function

Plant roots create a class of chemicals known as strigolactones. Strigolactone encourages the growth of parasitic plants like Strigalutea and other members of the genus Striga that grow in the roots of the host plant. Because they form a mutualistic connection with these plants and offer phosphate and other soil nutrients, strigolactone plays a crucial part in the symbiotic fungi's ability to identify the plant. Strigolactone has a function in the enhancement of lateral root development and root hair elongation, as well as the inhibition of shoot branching in plants [36].

3. Role of phytohormone in stress

Due to their effects on hormonal and nutritional imbalances, stress conditions have a significant negative impact on crop productivity. Some common stresses that have a negative impact on plant growth and development include salinity, drought, heavy metals, nutrient deficiency, and pathogens. These stresses have an impact on plant growth in one way or another. A single stress can negatively impact several plant functions in a variety of ways. For instance, salt reduces plant development by generating hormonal abnormalities, ion toxicity, oxidative stress, nutritional problems, and water stress. Plants adapt specific defence systems to deal with biotic and abiotic challenges in their native soil environments. To each given stimulus, several cellular signalling pathways are triggered [37]. The synthesis of phytohormones is accelerated by these signals. Signalling molecules called phytohormones control physiological and developmental processes in plants. There are several biotic and abiotic factors that influence hormone production, which substantially varies These hormones may have a significant impact on plant growth and development even at very low concentrations. Plant defence against environmental stresses depend heavily on hormonal signalling. The primary function of phytohormone production in plants is resistance to stress. Auxin, cytokinins, ethylene, gibberellins, and abscisic acid are the five main groups of phytohormones. Brassinosteroids, jasmonic acid, salicylic acid, and nitric acid have also been found as chemical messengers present in trace amounts in plants in addition to these well-known plant hormones. These hormones move throughout the plant body via the xylem or phloem transport stream.

The most investigated stress-responsive hormone among them is abscisic acid (ABA), which has a role in a variety of conditions include osmotic, drought, and cold stress. Plant processes including organogenesis, embryogenesis, and the development of vascular tissue are all regulated by auxin. A new class of plant hormones known as brassinosteroids affects processes such as flowering, senescence, and seed germination [38].

4. Abiotic stress and phytohormones

Abiotic stress like salt, low temperature, heat, drought, UV-radiation, elevated CO2, ozone, and heavy metals stress, are the major factors that reduce the growth of plants. There are various adaptations and ways by which plants protect them from the abiotic stress, and one such strategy is phytohormones produced by them. Phytohormones play a major role in some of the important functions in plants in how to respond to external environmental changes [39].

Abscisic acid (ABA), also called as the plant stress hormones as it is the most studied plant hormones under abiotic stress and has the important role in stress tolerance too. ABA activates specific signalling molecules which helps in activating the genes by signal transduction and activates set of genes through abscisic acid-responsive elements (ABRE) and Dehydration Responsive elements (DRE) pathways.in response to ABS LEA and dehydration proteins are also induced [40].

Auxin's primary role is to play an important role in plant growth and development, but auxin also plays an important role in abiotic stress tolerance. Functional genomics studies based upon the transcriptome analysis proves the upregulated genes related to auxins under abiotic stress conditions [41, 42]. Auxin level has been altered and PIN proteins play an important role in all kinds of abiotic stress like salt, drought, heat, heavy metal etc. As auxin plays a role in root architecture, so it helps in abiotic stress response by altering root physiology [43].

Cytokinin has a main role in growth and development like Auxin, but also it helps in stress signalling, which was proved by the transcriptomics studies. At stress forms cytokinin levels increase and decrease accordingly [44]. It was studied that the cytokinin levels initially drop down in less stress conditions but gradually increase as the stress increases. Lots of studies have been done and still more studies need to be done to clarify the statements [45].

Gibberellic acid, which is also called as germinating hormones also plays a role in abiotic stress tolerance. Studies has shown its role in all kinds of stress [46]. Experiments have shown its role in heat stress tolerance in Tomatoes [47], and chilling stress tolerance by increasing antioxidant activity in sprouts has also been proved [48]. Studies in *Arabidopsis thaliana* have shown that GA also helps in mitigating heavy metal stress via modulating antioxidants [49].

Salicylic acid (SA) serves as a key hormone in plant innate immunity, including resistance in both local and systemic tissue upon biotic attacks, hypersensitive responses, and cell death. Salicylic acid plays an important role in the growth and development of the plant for important physiological roles such as increasing the plant's response to stress conditions (biotic and abiotic) by increasing the resistance of the plant to System Acquired Resistance (SAR) by stimulating or changing the internal paper dissection endogenous signalling to withstand a large number of stresses [50]. Salicylic acid acts as a stimulant or transmitter of the cell to withstand environmental stress conditions such as drought, cold, heat, stress of heavy elements, and conditions of ammonia tension and also increases the plant's ability to withstand salt stress salt particularly harmful sodium chloride compound NaCl. This phenolic acid hormone plays important role in the regulation of plant growth, fruit ripening and development. It is involved in pathogenesis-related protein expression. It also has the ability to bind conjugate with some amino acids such as proline and arginine, which increase the plant's effectiveness in resisting environmental stresses and at the same time maintain systemic acquired resistance [51].

Salicylic acid and Jasmonic acid, hormones which are known for the biotic stress hormones also play a role in abiotic stress tolerance. In wheat application of SA and JA has shown to increase the germination during the drought stress [52]. Even exogenous application of SA helps in salt stress response in cucumbers [53] and reports have shown their role in heavy metal toxicity tolerance too [54].

Strigolactones are also very important hormones in plant microbe relations but also play a role in different stress. Moreover Strigolactones play a role in stress adaptation by cross talking with other plant hormones and playing a regulatory role [55].

5. Biotic stress and phytohormones

As soon as plat sense a stress response lots of signalling pathway is triggered in the plant. One of the most important event is alteration in calcium levels in plants, which in turn helps in signalling via PIP and activating the kinases enzymes. Calcium ions bins to calmodulin or calcium-dependent protein kinases (CDPKs), or phosphatases which can either phosphorylate/dephosphorylate specific transcription factors, and regulate the gene expression [56]. Although all plant hormones play a role in stress response both abiotic and biotic as they cross talk among each other and help in combating stress in coordinated manner, but few hormones are well studied and are like font line warriors in biotic stress tolerance, like abscisic acid, ethylene, salicylic acid, jasmonates.

Abscisic acid positively regulates or negatively regulates defence responsive genes depending upon the type of pathogen plant is facing and type of plant. It exerts its effect by upregulating some of the gene families like ABA-responsive elements (ABRE) and other transcription factors like MYC, MYB and NAC families [57]. As the herbivore attacks the plant, their secretions increase the ABA level in the plant. Research has been done in plants with the herbivore attack and mutant analysis too and it proves to be correct. Transcriptome analysis also prove the same [58]. ABA is also involved in plant antiviral defence, as infection with few viruses studied has shown to have increased accumulation of ABA in plants [59].

Salicylic acid, Jasmonic acid and Ethylene play an important role in biotic stress response. These are the key hormones which play an important role in plant defence against the pathogens and pests. Increased Salicylic acid levels protect the whole plants with the help of upregulation of Pathogenesis related genes (PR genes) [60]. Jasmonic acid helps in production of secondary metabolites like tannins, total phenols, total flavonoids, and lignin upon insect attack and helps in insect resistance in plants [61].

All these hormones and signalling pathways interact among each other to help plants fight against the stress. Plant adaptations and its development stages and cross talk of these biotic and abiotic stresses with help of different transcription factors help a plant to survive in harsh conditions.

6. Conclusion

A well-known fact is that plant growth, development and senescence are under the regulation of the system of natural growth regulators: natural inhibitors and phytohormones. These substances could be transported in the cell or even between the plant tissues and organs. Phytohormones are involved in wide range of functions, ranging from growth and development to biotic and abiotic stress tolerance. Efficiency of plant hormone is increased by their ability to crosstalk under different conditions. We can use research in plant hormones to improve crop growth and production, as they regulate complex signalling networks involving developmental processes and environmental stresses. Significant progress has been made in identifying the key components and understanding plant hormone signalling (especially salicylic acid, Jasmonic acid and Ethylene) Several recent studies provide evidence for the involvement of other hormones such as Abscisic acid, Auxin, Gibberellins, Cytokinins and Brassinosteroids in plant defence signalling pathways. To understand how plants coordinate multiple hormonal components in response to various developmental and environmental cues is a major challenge in research. It is important to note that the type of interactions and plant responses to stresses vary depending on the plant system as well as the time, quantity and the tissue where hormones are produced.

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