Chapter

Plant Growth Hormones

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Abstract

Many factors can cause and affect cell growth in the plant such as external (environmental) and internal factors; one of the most important internal factors is plant growth hormones. Many hormones required for cell growth, such as auxins, gibberellins, brassinosteroids, ethylene, jasmonates, salicylic acid, strigolactones and cytokinins which able to accelerate or promote growth, but, some hormone-like abscisic acid has an adverse effect on growth which increases seed dormancy by inhibiting cell growth. Also, plant hormones are able to breakdowns dormancy for many plants and can alleviate abiotic stress (salinity, extreme temperatures and, drought,...) which led to enhance germination and improve growth for many plants, whether naturally occurring in the plant or by adding it to the plant in its artificially formed or in the form of bio- or nano-fertilization in order to increase the productivity and improve its efficiency under extreme conditions. Therefore, this chapter will highlight and will provide data for the positive or/and negative effect of these hormones on many plants to achieve a rapid germination method. It will also shed light on the relationship of these hormones to some enzymes to accelerate growth.

Keywords: plant hormones, seed germination, dormancy, cell growth, inhibition

1. Introduction

Plant hormones (phytohormones) are not nutrients, but chemicals and not all plant cells respond to hormones, but those cells that do are programmed to respond at specific points in their growth cycle. The greatest effects occur at specific stages during the cell's life, with diminished effects occurring before or after this period [1].

Plants need hormones at very specific times during plant growth and at specific locations. They also need to disengage the effects that hormones have when they are no longer needed. The production of hormones occurs very often at sites of active growth within the meristems, before the cells have fully differentiated. After production, they have sometimes moved to other parts of the plant, where they cause an immediate effect; or they can be stored in cells to be released later. Plants can also break down hormones chemically, effectively destroying them. Plant hormones frequently regulate the concentrations of other plant hormones [2, 3].

2. Importance of plant hormones

The small amounts of plant hormones promote, control, influence and develop the growth from embryo to reproductive development, also, stress tolerance and pathogen defense. According to the importance of plant hormones in this chapter will be divided into two main points: first: the effect of plant hormones on germination and growth of plants under internal or external suitable conditions, second: the effect of plant hormones on the germination and growth of plants under internal or external unsuitable environmental conditions.

2.1 The effect of plant hormones on germination and growth of plants under internal or external suitable conditions

Seed germination is attracted to the effective growth of the embryo when appropriate environmental conditions are present, leading to seed rupture and the appearance of a small plant. There are five basic steps to germination: water imbibition, enzyme activation, initiation of embryo growth, rupture of the seed coat and emergence of seedling, seedling establishment [4, 5].

In the second step stage of germination (enzyme activation), after the absorption of water through the natural openings in the casing of the seed and spread through the tissues of the seed, gibberellins which activate the formation of the hydrolytic enzymes, mainly α- amylase in the aleurone cells, which are responsible for hydrolysis of storage macro-molecules such as starch and proteins and convert them into available forms to the embryo, usage to increase in size, and raise the osmotic content of the seed, to increase water potential [6, 7].

In addition, plant hormones have an important role in plant growth not only germination such as cytokinins (CKs) which influence cell division, the formation of shoot and helping in delay tissues senescence [8, 9]. Also, the ratios of Cytokinins and auxins affect most major growth periods during a plant's lifetime [10]. Also, Peptide hormones, control of cell division, expansion, and play crucial roles in plant growth and development [11]. Furthermore, gibberellins (Gas) strongly promote cell elongation in seedlings [12, 13]. It can also affect cell cycling in plant [14]. Meanwhile, the responses of **n**itric oxide (NO) are in germination, cell death [15] and regulate plant cell organelle functions (e.g. mitochondria and ATP synthesis in chloroplasts) [16].

For enhances and increases plant hormones production in the plants, many studies have proved the need to add plant hormones either directly (GA3, kinetin and cytokinins) [17, 18] or indirectly (humic substances, manures, magnetite, natural zeolites, *Moringa* extract and bio-fertilization) to increase or accelerate the productivity of plant hormones in the plant [19] indicated that, the presence of organic matter represented in compost which a source of hormones like substances as auxin-like activity and gibberellin-like activity. Similar results were obtained from [20]. Ref. [21] concluded that it is also possible that the production of plant hormones influences symbiotic bacteria, such as nodule N_2 fixing bacteria. During the establishment of the soybean (*Glycine max* L.) and *Bradyrhizobium japonicum* N_2-fixing symbiosis, the production of plant hormones can determine the bacterial population in the nodules by, for example affecting the available substrate for the use of rhizobium. The other significant and interesting view of the effects of soil bacteria on the production of plant hormones is the alteration they may reason in plant signaling pathways, resulting in the output of plant hormones from the host plant [22, 23]. Ref. [24] concluded that the magnetic treatments have the same affected for phytohormone production. Ref. [25] reported that the highest mean values of IAA, GA, and CK (12.70, 13.71, 11.06 μg/g FW), respectively were recorded with compost and zeolite mixture in comparison with control. Ref. [26] concluded that the addition of a mixture of organic fertilizers and soil amendments led to significant increment in indigenous hormones characterized in **i**ndole **a**cetic **a**cid (IAA), gibberellic acid (GA3), and cytokinins (CK), which led to a significant increase in morphological growth, floral characteristics and chemical composition of *Oenothera biennis*. In contrast [27] found that the application of HA inhibits indoleacetic acid (IAA) oxidase, thereby hindering the destruction of this plant growth hormone.

2.2 The effect of plant hormones on the germination and growth of plants under internal or external unsuitable environmental conditions

Sometimes even under favorable germination conditions (an adequate water supply, a suitable temperature and the normal composition of the atmosphere) seeds do not germinate. In this case, seeds are considered dormant. Seed dormancy is defined as an inactive phase in which the growth and development are deferred and the respiration is greatly reduced [28, 29]. Seed coat dormancy involves the mechanical restriction of the seed coat. GA releases this dormancy by increasing the embryo growth potential, and/or weakening the seed coat so the radical of the seedling can break through the seed coat. ABA affects the testa or seed coat growth characteristics, including thickness, and affects the GA-mediated embryo growth potential [5].

Hormones also can mediate endosperm dormancy: Endosperm in most seeds is composed of living tissue that can actively respond to hormones generated by the embryo. The endosperm often acts as a barrier to seed germination, playing a part in seed coat dormancy or in the germination process. Living cells respond to and also affect the ABA:GA ratio, and mediate cellular sensitivity; GA thus increases the embryo growth potential and can promote endosperm weakening. GA also affects both ABA-independent and ABA-inhibiting process within the endosperm [30]. In addition, [33] concluded that the prevented germination of some seeds of tomato [31], iris [32], and some varieties of cabbage was due to the present of inhibitors (ABA, parasorbic acid, and coumarin) which cases distributed in plants and to possess the property of inhibiting seed germination and other growth phenomena [5, 34].

Plant hormones affect seed germination and dormancy by acting on different parts of the seed such as [35] found that the inhibitors in seeds of peach were at least one of the factors controlling in germination by preventing or retarding cell division of the radical. In *Lupinus angustifolius*, the contents of auxins increased through the 5th day of germination and started to decrease on the 7th day. Oppositely, gibberellins contents were decreased first then increased later, so it was clear that there was inversely related between auxins and gibberellins [36]. The germination percentage and germination rate of four studied Acacias (*A. saligna*, *A. sophorae*, *A. cyclopis,* and *A. melanoxylon*) were correlated positively with endogenous promoting and negative with endogenous inhibiting substances in their cotyledons plus embryo [37].

The promotion of germination by gibberellin and cytokinins has been demonstrated in many seed species [38, 39]. Ref. [40] treated the seeds of *Acacia longifolia*, with GA3 at 100 and 200 ppm and found that the higher GA3 concentration (200 ppm) was more effective in increasing germination while the concentration of 500 ppm was the best in the case of *Acacia catechu* [41].

Ref. [42] found that fresh seed of *Acacia nilotica* and *Acacia albida* were fully germinated when soaked in a solution of GA_3 at 200 ppm for 12 h. While soaking seeds of *Acacia nilotica* in gibberellic acid (100 or 300 ppm for 16 h) was the best [43]. Ref. [44] studied the effect of GA3 at a concentration of (50 ppm) on 16 species (four Acacia species), and found a high germination percentage for all species.

The effect of gibberellic acid and cytokinins were also recognized on the germination of other plant species seeds. Ref. [45] studied the effect of Kinetin at different concentrations on the seed germination of *Acer tataricum*, and found the highest germination percentage at the concentration of 500 ppm. Ref. [46] found the best germination percentage on soaking the seeds of *Trifolium pratense* in 50 ppm 6-benzylaminopurine (6-BAP). Ref. [47] studied the effect of Kinetin at different conc. (10, 25, 50 and 100 ppm) in the seeds of *Cassia sophera*, and found the highest germination percentage at 100 ppm. The treatment of freshly harvested and 1 year old seeds of soybean (*Glycine max*) with, 1 ppm 6-BAP increased the germination percentage from 50 to 85% in freshly harvested seeds and to 75% in the older seeds [48]. The effect of kinetin and 6-BAP on the seed germination of *Vicia faba* were studied, [49] found an increase in its germination percentage at the concentration of 100 ppm kinetin. While [50] found that, the highest germination percentage for faba bean (*Vicia faba* L.) was achieved at the concentration of 100 ppm 6-BAP. Also [37, 51] reported that the storage has an adverse effect on the hormone within the seeds of *Acacia saligna*, *Acacia Cyclopes*, *Acacia nilotica* and *Acacia albida*, which contained the lowest value of GA3, IAA and the highest content of phenols.

Plant hormones can also alleviate abiotic stress such as drought, extreme temperatures, and salinity [52, 53]. The action of these hormones in response to situations of stress can be developed through synergistic or antagonistic activities [54]. Also, [55] concluded that the plant growth regulators like ABA, JA, and ethylene are involved in the regulation of the plant response to abiotic stress. Cytokinins are also able to enhance seed germination by the alleviation of stresses such as salinity, drought, heavy metals and oxidative stress [56–59]. Ref. [60] found that GA_3 plays an important role in the growth and metabolism of microalgae *Chlorella vulgaris* exposed to heavy metal stress and its adaptation ability to a low-level polluted aquatic environment. Meanwhile, gibberellin leads to enhancement for *Zea mays* seedling growth and establishment under saline soil conditions by improving nutrient levels and membrane permeability [61]. Also, hormonal interactions between plant and rhizosphere bacteria can affect plant tolerance to stress. As such, the plant and bacteria can be genetically modified so that they can perform more optimally under a range of conditions, including stress [62].

The decreased cytokinin and gibberellic acid (GA3) and increased abscisic acid contents are often observed responding in plants subjected to environmental stresses [63, 64]. Exogenous application of plant growth regulators [such as cytokinin or antioxidants (ascorbic acid) [65], Moringa (*Moringa oleifera*) leaves extract [66, 67], humic acid (HA) [68], or seaweed extract (SE) [69] could be an alternative strategy to ameliorate, minimizing or alleviating the adverse effects of abiotic stress factors on plant growth which led to promoting plant growth and development metabolism in plants. Several studies also indicated that results on wheat [70]; and on spinach [71]. Ref. [72] reported that the foliar application of Moringa (*Moringa oleifera*) leaves extract MLE is proved to be the most effective PGR in reducing plant (*Lagerstroemia indica* L. seedlings) exposure to salinity stress.

Also, bio-fertilization has beneficial microorganisms that increasing plant hormones, which led to enhances yield, plant growth and nutrient uptake under various environmental conditions such as salinity [73–76], drought and low fertility supply [77–79], especially that some endomycorrhizal fungi (Arbuscular mycorrhizal fungi) have been proven to improve drought stress; they colonize bio-trophically the root cortex and develop an extra-metrical mycelium that helps the plants to acquire mineral nutrients from the soil particularly those, which are immobile. They can under drought conditions stimulate growth-regulating substances, increase photosynthesis, improve osmotic adjustment, optimize hormonal balance and enhance water uptake [80].

Numerous studies have found also, that it can be alleviation of salt stress on peanut [81]; on pumpkin plants [82]; on *Moringa peregrina* plants [83] by using foliar application of nano-fertilizers. Also, [84] reported that nano Zn-Fe oxide plays a significant role importance in alleviating salt stress, oxidative damages on plant cells by activation of certain antioxidant enzymes. In addition, [85] reported that the application of nano-oxide and bio-fertilizer reduced the negative effects of salinity due to its contributed to produce hormones.

3. Conclusions

This chapter was indicated by many studies that the plant hormones, including IAA, cytokinins, ethylene, gibberellins, and brassinosteroids, can positively affect seed germination and seedling growth, for many plants as mentioned previously in the chapter, under favorable conditions. While ABA has an adverse on affect seed germination and the growth.

Also, this chapter sheds the light on the important role of soil bacteria in the production of plant hormones or as an alternative in the case of the low rate of plant hormones in the plant, which led to hence seed germination, growth, and hence crop production.

In addition, this chapter provided many studies that prove that the plant hormones very important to overcome dormancy or growth under stress condition. Also, shed the lights on the importance of the exogenous application of plant growth regulators (cytokinin or antioxidants, Moringa leaves extract, humic acid, or seaweed extract, bio- or nano fertilizers) for enhancing the productivity of plant hormones which led to increased cell growth.

Finally, it can be stated that the plant hormones are essential for cell growth, whether under normal conditions or under stress conditions.

Conflict of interest

The author declares that she does not have any conflict of interest.

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