The Role of Plant Hormone on Root Development

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ABSTRACT

Plant hormones, commonly referred to as phytohormones, are distinct chemical substances that are created by plants and are essential in controlling numerous aspects of plant growth and development. These hormones are created in particular sections of the plant, like the shoot apex or the root meristem, and are then transferred to other parts of the plant where they have their effects in tiny, concentrated amounts. The influence of a particular hormone can vary depending on the target tissue it acts upon, and the interplay between different hormones is crucial for proper plant development. Auxin, abscisic acid, ethylene, gibberellins, cytokinins, salicylic acid, strigolactones, brassinosteroids, and nitrous oxide are the most common plant hormones. Each hormone has specific roles and functions in plant physiology. For example, auxin is involved in controlling cell elongation, tropisms, and root initiation, while abscisic acid regulates seed dormancy and stomatal closure in response to water stress. Ethylene influences fruit ripening and senescence, and gibberellins promote stem elongation and seed germination. Cytokinins regulate cell division and shoot formation, while salicylic acid is involved in plant defense mechanisms against pathogens. Strigolactones are important for root development and symbiotic interactions, and brassinosteroids play a role in various growth processes. Nitrous oxide, although primarily known for its role in atmospheric chemistry, has been shown to have effects on plant growth as well. Under stressful conditions, such as drought, high salinity, or extreme temperatures, these hormones play a crucial role in enabling plants to tolerate and adapt to their surroundings

Keywords: Arabidopsis, Cyclin Gene, Different Hormones, Pin Family Protein, Root Epidermal Cells

Introduction

The delicate interaction of numerous hormones, including auxin, cytokinin, gibberellin, and abscisic acid, governs root growth in plants. Each hormone has its own synthesis process and signalling mechanism, which helps to regulate root development overall. Furthermore, external growth regulators such as light and temperature, as well as intrinsic growth regulators such as hormones, play critical roles in plant growth and development. As sessile organisms, plants must adapt their growth patterns and architectural features in response to environmental fluctuations. This necessitates coordinated hormone signaling systems that orchestrate plant growth and development through complex and interconnected pathways.

Plant hormones, also referred to as phytohormones or plant growth factors, are crucial signaling molecules that are indispensable for proper plant growth. Unlike animals, which possess specialized glands for hormone secretion, in plants, hormones are produced in every cell of plants, albeit in low concentrations. These hormones play a variety of roles in plant physiology, from dictating stem, leaf, and flower formation to controlling fruit development and even programmed cell death.

MATERIAL AND METHODS

Plants, as immobile organisms, have evolved intricate mechanisms to cope with challenging environmental conditions by modulating internal metabolic processes. Among these mechanisms, plant hormones play a crucial role in facilitating plant adaptation to stressful environments. This review aims to explore the diverse functions of different plant hormones in the initiation and development of roots. By understanding the specific roles of these hormones, we can gain valuable insights into the complex regulatory networks underlying root growth and enhance our knowledge of plant biology

Auxin

The formation of lateral roots in plants is regulated by auxin, as demonstrated by previous studies (Blakely et al., 1982; Laskowski et al., 1995). Various mutations associated with auxin have been identified in Arabidopsis, each impacting different phases of lateral root growth (Celenza et al., 1995). For instance, the alf3 mutation halts organ development immediately after emergence, while the alf4 mutation impedes the initiation of lateral roots (Celenza et al., 1995). These mutations exhibit diverse morphologies, indicating the involvement of indoleacetic acid (IAA) in multiple stages of lateral root development. Specifically, IAA plays a crucial role in establishing a population of rapidly dividing pericycle cells, which subsequently differentiate into hormone-autonomous meristems (Laskowski et al., 1995). Auxin possesses a unique capability among plant hormones to facilitate both long-distance and short-distance movement. The AUX/LAX and PIN protein families act as key regulators of cellular auxin transport by enabling influx and efflux, respectively. PIN1, in particular, regulates the unidirectional transport of auxin from the shoot apex to the root, known as rootward auxin transport.

Cytokinin

Cytokinins play a crucial role as signaling molecules in plants, governing the regulation of cellular breakdown, growth, and developmental processes. These hormones, along with the auxin signaling hormone, are synthesized by living cells present in the roots and shoots of intact plants (Miyawaki et al., 2004; Nordström et al., 2004; Aloni et al., 2005; Tanaka et al., 2005; Aloni et al., 2003; Ljung et al., 2005). Nevertheless, the production of these hormonal signals is meticulously controlled by multiple factors, which include the spatial distribution of the synthesizing cells within the plant organism, the developmental phase of the cells, and external environmental stimuli. Notably, indoleacetic acid (IAA) is primarily produced in young shoot organs, while cytokinins are predominantly synthesized in the root tips (Aloni et al., 2003, 2006).

To exert control over plant development and differentiation, these hormonal signals propagate from their site of synthesis through specific structural channels, utilizing various transport mechanisms (Aloni, 2004; Aloni et al., 2005Cytokinins are carried upward from the root cap through plasmodesmata, which maintain a continuous symplastic route, within the meristematic and elongation zones

(Scheres et al., 2002). Furthermore, cytokinins are delivered through the xylem vessels in the differentiation zone, using the transpiration stream as a conduit. Their key aims are growing shoot organs with high transpiration rates. Cytokinins have a favourable influence on shoot organ development by regulating developmental processes and aiding shoot growth (Howell et al., 2003; Rahayu et al., 2005). Cytokinins, on the other hand, act as negative regulators in the context of root growth and development (Werner et al., 2001, 2003).

Abscisic Acid

ABA is known as a stress hormone in plants and serves a purpose in many areas of plant growth and development. Its activities include embryo development regulation, seed dormancy regulation, transpiration regulation, and reaction to environmental adversities such as cold, salt, and drought (Zeevaart and Creelman, 1988; Campalans et al., 1999). ABA is important in facilitating root-to-shoot signalling, which leads to a reduction under shoot growth while maintaining primary root elongation, especially in dry situations. ABA inhibits the development of shoots and roots under regular watering circumstances. When water availability is reduced and ABA levels rise, ethylene production in response to compacted soil is prevented, ensuring continued root expansion (Sarquis et al., 1991; Roberts et al., 2002; Sharp and LeNoble, 2002).

ABA promotes the emergence of lateral roots in plants alongside to its function as primary root elongation. Latest study suggests ABA in modulating the inhibitory impact of high nitrate levels on Arabidopsis lateral root growth (Signora et al., 2001; Smet et al., 2003). Particularly, two ABA-insensitive mutants, abi4 and abi5, substantially lowered the high-nitrate-induced inhibition of lateral roots. Furthermore, this pathway is unaffected by auxin and can be triggered by both high NO3- levels and exogenous ABA. Despite these advances, the specific mechanism by which ABA affects root growth is still unknown, prompting additional research in the area.

Gibberellins

The histological processes involved in the initiation of adventitious roots in the hypocotyls of Pinus radiata D. rely on the presence of indole-butyric acid (IBA) for both the pre-initiative and post-initiative stages of root growth (Smith & Thorpe, 1975). The pre-initiative phase experiences significant inhibition when exposed to kinetin; however, this inhibition is overcome once meristemoids begin to develop. The application of gibberellic acid (GA3) at different stages yields three distinct effects. During the pre-initiative phase, GA3 acts as an inhibitor, but if administered during the first discernible stage of root initiation, it greatly enhances rooting. However, once meristemoids have formed, GA3 prevents further root production (Smith & Thorpe, 1975). The regulation of ARR1, a key gene involved in root development, involves the convergence of gibberellin signaling pathways, with gibberellins repressing the expression of ARR1.

Ethylene

Ethylene plays a crucial role in plant development. It regulates the formation of root nodules in leguminous plants, hinders the growth of storage organs such as tubers and bulbs, stimulates root initiation in numerous plant species, and influences the development of storage organs in a suppressive manner. Additionally, ethylene promotes flowering in certain species while having no effect on others. Moreover, in cucurbits, it induces the production of female flowers as opposed to male flowers (Schaller, 2012). One notable area of study related to plant morphogenesis and cell polarity is the initiation of root hairs formation in *Arabidopsis thaliana*. This plant's root-hair development mechanism can be used to study cell polarity and how it's utilised in plant morphogenesis. Root epidermal cells normally grow polarised, with root hairs emerging at the apical ends. A mutant known as rhd6, on the other hand, exhibits three separate defects: a decrease in the number of root hairs, a basal shift in the emerging site of root hairs, and an increased incidence of epidermal cells with numerous root hairs. These findings strongly suggest that the RHD6 gene is involved in the establishment or reaction to root epidermal cell polarity, as well as the beginning of root hairs (Masucci & Schiefelbein, 1994).

RESULTS AND DISCUSSION

Table 1: List of Plant hormones and their major roles in root initiation

HORMONE	**FUNCTION&protein involved in root initiation**	**REFERENCES**
AUXIN	Role in gravitropism (AUX/LAX &PIN 1)	Overvoorde, 2010
CYTOKININ	Transcriptional regulation of stress related genes (ARR1,ARR5,ARR3)	Aloni, *et al.*,2006
ABSCISIC ACID	Root growth regulation and adaptation to environmental change (CKX1,CKX3,CKX4,&CKX6)	Chen, *et al.*,2006
GIBBERELLIN	Transcription shown by DELLA protein (GAI, RGA,RGL1,RGL2,RGL3)	Tanimoto, 2005
ETHYLENE	Promotes cross talk during germination(ETR1,ETR 2,ERS 1,ERS 2)	Jackson, 2018

CONCLUSION

It is apparent multiple growth and developmental processes are greatly controlled by the relationships between various plant hormones. Plants have to incorporate a variety of internal and external signals while they develop and mature in order to decide their overall form in conjunction with their innate genetic programming. These signals are mediated by several hormones, namely auxin, cytokinin, gibberellins, abscisic acid, and ethylene. Each of these hormones exerts its regulatory effects at low concentrations, controlling various aspects of plant growth and development. These plant hormones participate in the complex regulation of plant structure and function by coordinating their individual activities.

FUTURE SCOPE

As our planet faces imminent environmental challenges caused by pollution and the depletion of resources, the development of resilient plant varieties holds great promise as a potential solution. Extensive scientific investigations are needed to comprehensively examine the complex signaling mechanisms that govern plant responses. By gaining a deeper understanding of these intricate pathways, researchers can harness this knowledge to create novel plant populations with enhanced tolerance and adaptability. Through dedicated and rigorous research efforts, we can pave the way for innovative strategies to mitigate the pressing environmental issues and ensure a sustainable future.

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