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REVIEW ARTICLE

GROWTH HORMONE REGULATION AND ITS ROLE IN PLANTS DEVELOPMENT

***, [1]Neeta Dwivedi, [1]Kalpana Singh, [2]Sonia Goel and [1]Rosin, K. G.**

[1]Water Technology Centre, Indian Agricultural Research Institute, New Delhi, 110012, India
[2]National Research Centre for Plant Biotechnology, IARI, New Delhi-110012, India

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ABSTRACT

Plant growth substances are the organic substances synthesized by the plant that regulate, retard or modify plant physiological activities. They can move within the plant from the site of synthesis to the site of action. Growth regulating chemicals that have positive influence on major agronomic crops are of immense value. These growth regulators are mainly important for preventing lodging in cereals, preventing pre-harvest sprouting, fruit drop, synchronizing maturity to facilitate mechanical harvest, hastening maturity to decrease turnover time, reducing labour requirements. Studies conducted on major grain crops, such as corn, soybean, wheat and rice have identified material capable of altering individual agronomic characteristics like lodging, plant height, seed number and maturity. Commercial application of plant hormone have been limited to the use of gibbrellic acid, Indole acetic acid and cytokinins. Crop performance have been shown to increase significantly with the application of these growth regulator.

INTRODUCTION

Plants need light, CO_2, water and mineral including nitrogen in soil for its growth. With these conditions the plant has the ability to transform some simple materials in to complex organic substances that compose all living organism. In this way, plant hormone or phytohormone have a very important function or activity in the growth regulation. Plant hormones are signal molecules produced naturally by plants and occur in extremely low concentrations, regulating their own growth by controlling or modifying plant growth processes. The term 'Phytohormone' was coined by **Thimann in 1948**. Hormones also determine the formation of flowers, stems, leaves, the shedding of leaves, and the development and ripening of fruit. When natural or synthetic substances are used in the same way, these are called plant growth regulators. Plant hormones shape the plant, affecting seed growth, time of flowering, the sex of flowers, senescence of leaves, and fruits and also affect the tissues growth, leaf formation, stem growth, fruit development, ripening, plant longevity and even plant death. Hormones are vital to plant growth, and, lacking them, plants would be mostly a mass of undifferentiated cells. So they are also known as growth factors or growth hormones. Agriculturists all over the world have developed certain unusual methods by which they successfully cultivate the crop plants. It is only in recent year's plant physiologists discovered how plant hormones can be effectively used in agriculture, horticulture, pomiculture and other related fields.

Corresponding author: Neeta Dwivedi,
Water Technology Centre, Indian Agricultural Research Institute, New Delhi, 110012, India.

As described earlier, plant hormones have a wide variety of effects and most of these responses are concentration dependent. Fortunately, phyto-chemists have also identified many synthetic hormones, some of which are more potent than natural hormones. Experimentation and experience have shown that the judicial use of hormones or combination of hormones can be employed in agriculture and related industries to get the maximum benefit. Quantity and quality of agricultural products are very important factors in the agricultural economics. There are many areas in agriculture, horticulture, pomiculture, moriculture, etc., where phytohormones can be used in successful cultivation to obtain greater yields. The high percentage of germination of sown seeds in the field has a bearing on the output. Pretreatment of seeds with IAA, NAA, GA, etc. has been found to be very effective not only in increasing the percentage of germination but also in the total yield of the crop plants. Suitable concentration and combination have to be determined for each crop.

Classes of plant hormones

Plant development can be dramatically influenced by a set of five structurally simple phytohormone i.e. auxins, ethylene, cytokinin, abscic acid and gibbrelins, some of which are made up of many different chemicals that can vary in structure from one plant to another. The chemicals are each grouped together into one of these classes based on their structural similarities and on their effects on plant physiology (**Klee *et al*., 1994**). Other plant hormones and growth regulators are not easily grouped into these classes; they exist naturally or are synthesized by humans or other organisms, including chemicals that inhibit plant growth or interrupt the physiological processes within plants. Each class has positive as well as inhibitory functions, and most often work in tandem with each other, with varying ratios of one or more interplaying to affect growth regulation.

(1) Auxins

Auxins are hormones involved in plant-cell elongation, apical dominance, and rooting. A well known natural auxin is indole-acetic acid (IAA) which is produced in the apical meristem of the shoot. Auxin was identified as a plant growth hormone because of its ability to stimulate differential growth in response to gravity or light stimuli (**Zhao, 2011**). The application of IAA after removing the seeds causes the fruit to enlarge normally. Synthetic auxins are chemicals that have synthesized several inexpensive compounds similar in structure to IAA (**Abel *et al*., 1994**). Synthetic auxins, like naphthalene acetic acid, of NAA, are used extensively to promote root formation on stem and leaf cuttings (**Guilfoyal *et al*., 1998**). Gardeners often spray auxins on tomato plants to increase the number of fruits on each plant. When NAA is sprayed on young fruits of apple and olive trees, some of the fruits drop off so that the remaining fruits grow larger. When NAA is sprayed directly on maturing fruits, such as apples, pears and citrus fruits, several weeks before they are ready to be picked; NAA prevents the fruits from dropping off the trees before they are mature. The fact that auxins can have opposite effects, causing fruit to drop or preventing fruit from dropping, illustrates an important point. The effects of a hormone on a plant often depend on the stage of the plant's development. NAA is used to prevent the undesirable sprouting of stems from the base of ornamental trees.

Plant stems contain a lateral bud at the base of each leaf. In many stems, these buds fail to sprout as long as the plant's shoot tip is still intact. The inhibition of lateral buds by the presence of the shoot tip is called apical dominance. If the shoot tip of a plant is removed, the lateral buds begin to grow. If IAA or NAA is applied to the cut tip of the stem, the lateral buds remain dormant. This adaptation is manipulated to cultivate beautiful ornamental trees. NAA is used commercially to prevent buds from sprouting on potatoes during storage. Another important synthetic auxin is 2, 4-D, which is an herbicide, or weed killer.

It selectively kills dicots, such as dandelions and pigweed, without injuring monocots, such as lawn grasses and cereal crops. Given our major dependence on cereals for food; 2,4-D has been of great value to agriculture. A mixture of 2, 4-D and another auxin, called Agent Orange, was used to destroy foliage in the jungles of Vietnam. A non-auxin contaminant in Agent Orange has caused severe health problems in many people who were exposed to it. Several genes rapidly upregulated by auxin application have been identified (**Abel and Theologis, 1996**), of which two classes are described briefly. **McClure *et al*. (1989)** characterized the so-called small auxin up RNA (SAUR) genes from soybean, some of which are auxin regulated.

(2) Abscisic acid

Abscisic acid (ABA), also known as abscisin II and dormin, is a plant hormone. ABA plays a significant role in the regulation of many physiological processes of plants including bud dormancy (**Fuji 2014**). ABA was originally believed to be involved in abscission. It is often used in tissue culture systems to promote somatic embryogenesis and enhance somatic embryo quality by increasing desiccation tolerance and preventing precocious germination. ABA is also employed to induce somatic embryos to enter a quiescent state in plant tissue culture systems and during synthetic seed research. Application of exogenous ABA improves in-vitro conservation and the adaptive response of plant cell and tissues to various environmental stresses. ABA can act as anti-transpirant during the acclimatization of tissue culture-raised plantlets and reduces relative water loss of leaves during the ex vitro transfer of plantlets even when non-functional stomata are present. ABA-mediated signaling also plays an important part in plant responses to environmental stress and plant pathogens (**Zhu, 2002; Seo and Koshida, 2002**). The plant genes for ABA biosynthesis and sequence of the pathway have been elucidated (**Nambara, 2005; Milborrow, 2001**).

ABA also inhibits the division of cells in the vascular cambium, adjusting to cold conditions in the winter by suspending primary and secondary growth. Abscisic acid is also produced in the roots in response to decreased soil water potential and other situations in which the plant may be under stress (**Meyer *et al*., 1994**). ABA then translocation to the leaves, where it rapidly alters the osmotic potential of stomatal guard cells, causing them to shrink and stomata to close. The ABA-induced stomatal closure reduces transpiration, thus preventing further water loss from the leaves in times of low water availability. A close linear correlation was found between the ABA content of the leaves and their conductance (stomatal resistance) on a leaf area basis.

Several ABA-mutant *Arabidopsis thaliana* plants have been identified and are available from the Nottingham Arabidopsis Stock Centre - both those deficient in ABA production and those with altered sensitivity to its action (**Leung *et al*., 1994**). Plants that are hypersensitive or insensitive to ABA show phenotypes in seed dormancy, germination, stomatal regulation, and some mutants show stunted growth and brown/yellow leaves. These mutants reflect the importance of ABA in seed germination and early embryo development.

(3) Gibberellins

In the 1920's scientists in Japan discovered that a substance produced by the fungus *Gibberella* caused fungus-infected plants to grow abnormally tall. The substance, named gibberellin, was later found to be produced in small quantities by plants themselves. It has many effects on a plant, but primarily stimulates elongation growth. Spraying a plant with gibberellins will usually cause the plant to grow to a larger than expected height, i.e. greater than normal. Like auxins, gibberellins are a class of hormones that have important commercial applications. Almost all seedless grapes are sprayed with gibberellins to increase the size of the fruit and the distance between fruits on the stems. Beer makers use gibberellins to increase the alcohol content of beer by increasing the amount of sugar produced in the malting process. Gibberellins are also used to treat seeds of some food crops because they will break seed dormancy and promote uniform germination.

(4) Ethylene

The hormone ethylene is responsible for the ripening of fruits. Unlike the other four classes of plant hormones, ethylene is a gas at room temperature. Ethylene gas diffuses easily through the air from one plant to another. The saying "One bad apple spoils the barrel" has its basis in the effects of ethylene gas. One rotting apple will produce ethylene gas, which stimulates nearby apples to ripen and eventually spoil because of over ripening. Ethylene is usually applied in a solution of ethylene a synthetic chemical that breaks down and releases ethylene gas. It is used to ripen bananas, honeydew melons and tomatoes. Oranges, lemons, and grapefruits often remain green when they are ripe. The application of ethylene to green citrus fruit causes the development of desirable citrus colors, such as orange and yellow. In some plant species, ethylene promotes abscission, which is the detachment of leaves, flowers, or fruits from a plant. Cherries and walnuts are harvested with mechanical tree shakers. Ethylene treatment increases the number of fruits that fall to the ground when the trees are shaken. Leaf abscission is also an adaptive advantage for the plant. Dead, damaged or infected leaves drop to the ground rather than shading healthy leaves or spreading disease. The plant can minimize water loss in the winter, when the water in the plant is often frozen.

tissues in the laboratory. A high ratio of auxins to cytokinins in a tissue-culture medium stimulates root formation. A low ratio promotes shoot formation. In plants, the cytokinin (CK) phytohormones regulate numerous biological processes, including responses to environmental stresses, via a complex network of CK signaling (**Ha *et al*., 2012**). Cytokinins are also used to promote lateral bud growth in flowering plants. A similar enzyme activity has also been observed in extracts from plant sources (**Blackwell and Horgan, 1994**) but because of its instability, the enzyme has only been partially purified (Chen and Ertl, 1994). The enzyme is predominantly localized in the endosperm (Martin *et al*., 1993). Mechanical wounding and herbivory have been shown to increase CK concentration that increases plant resistance to insects by stimulating wound-inducible gene expression and by inducing the accumulation of insecticidal compounds (**Smigocki *et al*., 1993**). Elevated CK concentrations also cause higher inducibility of a plant endogenous cytochrome P450 gene involved in the synthesis of a variety of secondary plant metabolites. It was also suggested that increased CK concentration may contribute to tissue repair by stimulating cell division (**Crane and Ross, 1986**).

The importance of CKs for plant physiological alterations (such as green island formation) and for regulation of altered organogenesis (such as rhizobial nodulation and gall formation) have recently gained much interest. Data collected on numerous biological models suggest potentially converging mechanisms for plant–microbe and plant-endophagous insect symbioses and point towards a key regulatory role of CKs in many biotic interactions.

Table 1. An overview of plant hormone and their functions

Hormones	Location in plants	Doses	Major functions
Auxin	Embryo of seeds, meristems of apical buds, young leaves.	10^{-10} to 10^{-6} M	Stimulates stem elongation (low conc. only), root growth cell differentiation and branching; regulates development of fruits; enhances apical dominance; functions in phototropism and gravi-tropism; promote xylem differentiation; retards leaf abscission.
Cytokinin	Synthesized in roots and transported in other organs.	0.1-10µm	Affect root growth and differentiation, stimulate cell division and growth, stimulate germination, delay senescence.
Gibberellin	Meristems of apical buds and roots, young leaves, embryo.	2.5 g/kg	Promote seed and bud germination ,stem elongation and leaf growth, stimulate flowering and development of fruit; affect root growth and differentiation.
Brassinosteroid	Seeds, fruits, shoots, leaves and floral buds	0.1 mg/kg	Inhibit root growth, retard leaf abscission, promote xylem differentiation.
Abscisic acid	Leaves, stem, roots and green fruits	100 mg/kg	Inhibit growth; closes stomata during water stress, promote seed dormancy.
Ethylene	Tissues of ripening fruit, nodes of stems aging leaves and flowers.	100 µM	Promotes fruit ripening, opposes some auxin effects, promotes or inhibits growth and development of roots, leaves and flowers depending on species.

Source: books.google.co.in/books?isbn=8131724093

(5) Cytokinins

Cytokinins are plant growth promoting hormones involved in the specification of embryonic cells, maintenance of meristematic cells, shoot formation and development of vasculature. Cytokinins have also emerged as a major factor in plant–microbe interactions during nodule organogenesis and pathogenesis. Microbe-originated cytokinins confer abnormal hypersensitivity of cytokinins to plants, augmenting the sink activity of infected regions (**Choi *et al*., 2011**). Cytokinins produced in the developing shoots, roots, fruits and seeds of a plant, cytokinins are very important in the culturing of plant

Additionally, the implication of CKs in signalling processes underlying plant growth and development, nutrient translocation and plant defences can positively impact the plants (through endogenous synthesis but also indirectly via their associated symbionts), but also sometimes their pathogens and herbivores. These interactions can have ecological consequences still to be unravelled and that can scale up to plant-associated communities (**Giron *et al*., 2013**)

Future perspectives

Plant hormones play important roles in regulating plant growth and defence by mediating developmental processes and signalling networks involved in plant responses to a wide range of parasitic and mutualistic biotic interactions. Understanding the cellular and molecular dialogue between plants, microbes and insects, which involves shared hormonal signals, and studying ecological and evolutionary implications can greatly improve our understanding of the interactions of plants with microbes and insects. Such information is important to understand the options for each partner to adopt an adaptive response to its biotic environment and the possible implication and origin of key universal regulatory molecules shared by many plant–biotic interactions.

Summary

Plant growth substances have key role in different physiological processes related to growth and development of crops. It is obvious that changes in the level of endogenous hormones due to biotic and abiotic stress alter the crop growth and any sort of manipulation including exogenous application of growth substances would help for yield improvement or at least sustenance of the crop. Plant growth hormones are organic substances produced naturally in the higher plants, controlling growth or other physiological functions at a site remote from its place of production, and active in minute amounts. Hormones usually move within plant from a site of production to site of action. Phytohormone are physiological intercellular messengers that are needed to control the complete plant lifecycle, including germination, rooting, growth, flowering, fruit ripening, foliage and death. In addition, plant hormones are secreted in response to environmental factors such as abundance of nutrients, drought conditions, light, temperature, chemical or physical stress. Hence, levels of hormones will change over the lifespan of a plant and are dependent upon season and environment.

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