Plant Growth Regulators (PGRs) and Their Applications: A Review

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Abstract
Plant growth regulators (PGRs), also referred to as plant hormones, are chemical substances that profoundly influence various aspects of plant growth and development even at very low concentrations. Their activities depend on concentration, plant physiological state, and environmental factors. PGRs regulate cell division, elongation, differentiation, and mediate responses to biotic and abiotic stress. They can be applied directly to roots, leaves, flowers, buds, and shoots to enhance stress resistance and optimize crop performance. PGRs are essential in horticulture, agriculture, floriculture, and viticulture, particularly in environments with suboptimal soil or harsh climatic conditions. This review discusses major PGR classes—including auxins, gibberellins, cytokinins, ethylene, abscisic acid, brassinosteroids, jasmonates, triacontanol, triazoles, and polyamines—and outlines their key roles and agricultural applications.

Keywords: Plant hormones, Auxins, Gibberellins, Cytokinins, Brassinosteroids, Triacontanol, Polyamines

1. Introduction

Plants synthesize hormones that regulate their growth, metabolism, and responses to environmental stimuli. These hormones, produced in specific tissues such as buds, roots, and shoots, are transported to target sites where they bind to receptors, triggering cascades of biochemical responses. Plant growth regulators (PGRs), both natural and synthetic, are used to manipulate these processes, improving crop yields, enhancing growth under stressful conditions, and optimizing developmental processes like flowering, ripening, or rooting.

The study and use of PGRs in agriculture have advanced since their discovery in the early 20th century, enabling precise control over plant physiological functions such as cell division, elongation, and senescence. Commercially available PGRs mimic natural hormones and are widely used as tools in modern agriculture and horticulture to overcome environmental limitations and increase productivity.

2. Auxins

Auxins are the first discovered and one of the most studied PGRs. Synthesized in meristematic tissues, auxins regulate cell elongation, root initiation, vascular differentiation, and apical dominance. They are distributed through polar transport mechanisms and play a crucial role in tropistic responses such as phototropism and gravitropism.

Major Functions:
- Promote stem and coleoptile elongation
- Initiate root formation in cuttings
- Promote apical dominance
- Delay leaf and fruit abscission

Common Applications:
- Synthetic auxins (e.g., IBA, NAA) are widely used for rooting in nursery practices.
- Fruit thinning and preventing premature fruit drop in crops like apples and citrus.

3. Cytokinins

Cytokinins promote cell division (cytokinesis) and differentiation. They are derived from adenine and synthesized mainly in roots. They travel upward through the xylem to influence shoot growth and leaf expansion.

Major Functions:
- Delay senescence by inhibiting protein degradation
- Promote nutrient mobilization
- Stimulate shoot initiation in tissue culture
- Regulate chloroplast development

Common Applications:
- Benzylaminopurine (BAP) and kinetin are used in tissue culture and seed germination.
- Applied as foliar sprays to improve grain-filling and delay aging in cereals.

4. Gibberellins
Gibberellins are diterpenoid acids that promote stem elongation, seed germination, flowering, and fruit development. Over 130 GAs have been identified, but GA3 is the most biologically active and commercially used.
Major Functions:
- Promote internode elongation
- Break seed dormancy
- Aid in flowering (e.g., in biennial plants)
- Increase fruit size
Common Applications:
- Boosting grape size and reducing fruit acidity
- Malting barley germination
- Inducing bolting in rosette-forming plants.

5. Ethylene
Ethylene is a gaseous hormone involved in fruit ripening, leaf abscission, and senescence. It acts as a stress hormone and interacts with other hormones like auxins and cytokinins.
Major Functions:
- Promote fruit ripening and senescence
- Trigger leaf and flower abscission
- Inhibit stem elongation
Common Applications:
- Ethephon is widely used to synchronize flowering and enhance ripening in crops like pineapples and bananas.
- Control of unwanted fruiting (e.g., thinning in cotton).

6. Abscisic Acid
Abscisic acid is a stress hormone involved in inhibiting growth and inducing dormancy. It plays a crucial role in stomatal closure during water stress and controls seed dormancy during unfavorable conditions.
Major Functions:
- Induce seed dormancy and prevent premature germination
- Regulate stomatal closure
- Enhance drought tolerance

Applications:
- Used in the horticulture industry to promote dormancy in nursery stocks
- Enhancing stress tolerance during seedling establishment.

7. Brassinosteroids
Brassinosteroids (BRs) are steroidal hormones that influence cell elongation, vascular differentiation, and stress tolerance. They interact synergistically with auxins and GAs.
Major Functions:
- Promote cell elongation and division
- Improve stress resistance (salt, drought, pathogens)
- Induce flowering in certain species
Common Applications:
- Foliar applications to improve stress tolerance and yield in cereal crops
- Used as biostimulants in organic agriculture.

8. Jasmonates
Jasmonic acid and its derivatives regulate responses to wounding, pest attack, and environmental stress. They are involved in secondary metabolite production and defense signaling.
Major Functions:
- Induce defense-related gene expression
- Promote tuber formation
- Inhibit root growth under stress Applications:
- Used to enhance pest resistance in crops
- Improve storage quality in fruits and vegetables.

9. Triacontanol
Triacontanol is a fatty alcohol found in plant waxes with strong growth-enhancing properties even at nanomolar concentrations.
Major Functions:
- Promote photosynthesis and protein synthesis
- Enhance root and shoot growth

- Improve yield and crop vigor
Applications:
- Commonly applied in vegetables and legumes to increase yield
- Used in organic farming as a biodegradable growth stimulant.

10. Triazoles
Triazoles are synthetic PGRs that inhibit gibberellin biosynthesis, reducing internode elongation and making crops sturdier.

Major Functions:
- Dwarfing and compact growth
- Improve stress tolerance
- Enhance chlorophyll stability Applications:
- Used in cereals to prevent lodging
- Promotes drought and salinity tolerance in seedlings.

11. Polyamines
Polyamines such as putrescine, spermidine, and spermine are organic compounds that regulate cell division, DNA replication, and response to stress.

Major Functions:
- Stabilize membrane structure
- Improve stress resistance
- Regulate flowering and fruit set Applications:
- Used to improve post-harvest shelf life of fruits
- Enhance abiotic stress tolerance in horticultural crops.

12. Conclusion
Plant growth regulators are indispensable tools in modern agriculture, offering precise biochemical control over plant growth, development, and stress responses. Their judicious use can lead to improved yields, quality, and stress tolerance, especially under non-ideal growing conditions. Future research should focus on molecular mechanisms, bioengineering of PGR biogenesis pathways, and sustainable use of natural PGRs in changing climatic conditions.