Available online at
http://agrospheresmagazine.vitalbiotech.org/

ISSN (E): 2582 – 7022

Agrospheres:e- Newsletter, (2025) 6(7), 22-25

Article ID: 750

The Role of Plant Growth Regulators in Modern Agronomy

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Open Access

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Article History
Received: 23.06.2025
Revised: 28.06.2025
Accepted: 02.07.2025

INTRODUCTION

Modern agronomy is increasingly focused on improving the efficiency, resilience, and sustainability of crop production. Traditional methods such as fertilization and irrigation, while essential, are often insufficient to optimize plant development under variable environmental conditions. This has led to the growing adoption of plant growth regulators (PGRs), also known as plant hormones, in commercial agriculture.

PGRs are compounds that regulate various aspects of plant growth and development by influencing cellular activities such as elongation, division, and differentiation. These substances are active at low concentrations and can have profound effects on plant physiology. Used appropriately, PGRs can enhance crop yields, reduce input costs, and improve quality. This article explores the classifications of PGRs, their physiological roles, and practical applications in modern agronomic systems.

2. Classification and Functions of Plant Growth Regulators

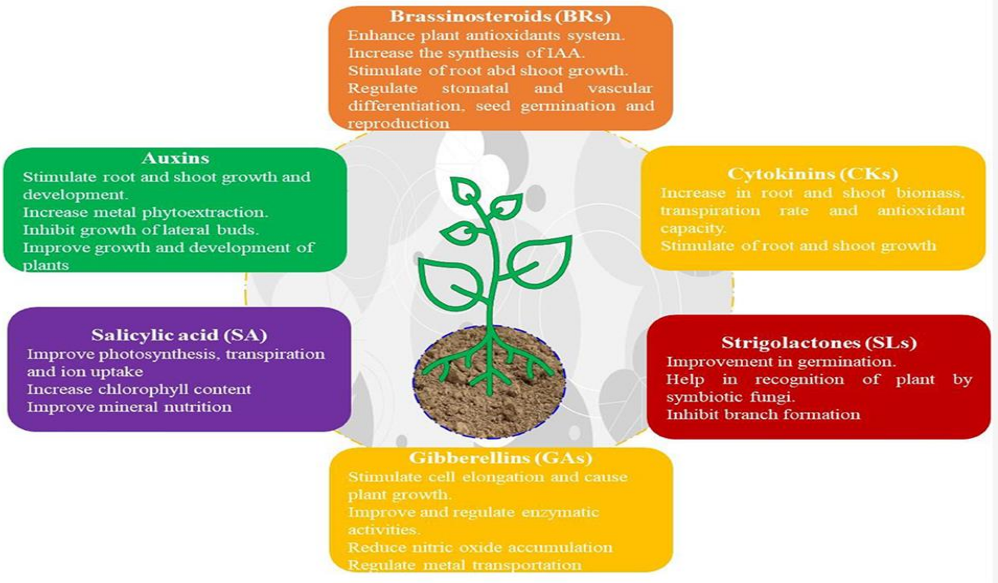
Plant growth regulators fall into five primary categories based on their chemical nature and biological function. These include:

2.1 Auxins

Auxins, such as indole-3-acetic acid (IAA), play a critical role in cell elongation, root initiation, and apical dominance. They are widely used to promote rooting in cuttings, prevent premature fruit drop, and manipulate plant architecture.

Agronomic applications:

- Inducing adventitious roots in plant propagation
- Enhancing fruit set in crops like tomatoes and grapes
- Controlling weed growth through synthetic auxins (e.g., 2,4-D)



Source: https://www.frontiersin.org

2.2 Gibberellins (GAs)

Gibberellins stimulate stem elongation, seed germination, and flowering. They are used in cereals to break dormancy and in fruit crops to increase size and improve quality.

Agronomic applications:

- Increasing internode length in sugarcane and rice
- Inducing uniform germination in barley and wheat
- Improving fruit shape in grapes and apples

2.3 Cytokinins

Cytokinins promote cell division and delay leaf senescence. They are used in tissue culture to stimulate shoot proliferation and are vital in maintaining the source-sink balance in crops.

Agronomic applications:

- Delaying senescence in leafy vegetables
- Enhancing tiller production in cereals
- Promoting branching and flower formation in horticultural crops

2.4 Ethylene

Ethylene is a gaseous hormone that regulates fruit ripening, leaf abscission, and stress responses. Though naturally produced, it is also applied synthetically to synchronize ripening and flowering.

Agronomic applications:

- Uniform ripening of fruits like bananas, mangoes, and tomatoes
- Inducing flowering in pineapple
- Promoting boll opening in cotton

2.5 Abscisic Acid (ABA)

ABA functions primarily as a stress hormone. It promotes stomatal closure under drought and plays a role in seed dormancy and maturation.

Agronomic applications:

- Enhancing drought tolerance in cereals and pulses
- Regulating water loss in greenhouse crops
- Improving seed quality through controlled dormancy

3. Role of PGRs in Crop Management

3.1 Enhancing Yield Potential

PGRs can directly influence yield by increasing the number and size of reproductive organs. For example, the application of gibberellins during the flowering stage in rice can increase panicle size and grain filling, while cytokinins improve sink strength by enhancing photosynthate distribution.

In maize, combining auxins and gibberellins has been shown to improve ear development and kernel size. Similarly, in wheat, the use of growth retardants can prevent lodging and facilitate higher nutrient use efficiency.

3.2 Managing Abiotic Stress

Plants under stress—drought, salinity, or temperature extremes—often have impaired hormone signaling. Application of ABA or ethylene inhibitors can improve resilience. ABA induces the production of stress-responsive proteins and reduces water loss by closing stomata.

In arid regions, pre-treating seeds with ABA or applying salicylic acid (a related stress-modulator) boosts germination and seedling establishment under water-deficit conditions.

3.3 Optimizing Plant Architecture

Growth retardants like paclobutrazol and chlormequat chloride inhibit gibberellin biosynthesis, reducing plant height and increasing stem strength. This is especially useful in cereals like wheat and rice, where lodging due to tall plants and high biomass can reduce yield.

Manipulating shoot-to-root ratios using auxins and cytokinins also helps optimize nutrient uptake in resource-limited environments.

3.4 Improving Quality Parameters

In fruit crops, PGRs enhance color, sugar content, and uniformity. For instance, ethylene promotes carotenoid accumulation in tomatoes, while gibberellins can reduce seed formation in grapes (parthenocarpy) and improve berry firmness.

In vegetables, PGRs are used to regulate flowering, improve shelf-life, and delay senescence, thereby adding market value.

4. Integration with Other Agronomic Practices

4.1 Seed Priming and Coating

Priming seeds with PGRs improves germination speed and uniformity, especially under suboptimal conditions. This technique is common in horticultural crops and cereals. Coating seeds with hormones and micronutrients also ensures better seedling vigor.

4.2 Synergy with Fertilizers and Irrigation

PGRs can increase the efficiency of nutrient uptake and water use. For example, cytokinins enhance nitrogen assimilation, while auxins improve root architecture for better water absorption. Integrating PGR use with fertigation (fertilizer via irrigation) maximizes input use efficiency.

4.3 Compatibility with Integrated Pest Management (IPM)

PGRs may indirectly affect pest resistance by strengthening plant tissues and activating defense-related pathways. Additionally, improved plant vigor from regulated growth can reduce susceptibility to diseases and pest attacks.

5. Challenges and Considerations

Despite their benefits, the use of PGRs requires precision. Over-application can lead to adverse effects such as abnormal growth, delayed flowering, or yield reduction. Moreover, the response to PGRs is influenced by plant species, developmental stage, and environmental conditions.

5.1 Environmental Concerns

Some synthetic PGRs may persist in the soil and affect non-target organisms. Proper regulation and monitoring are needed to prevent ecological imbalance.

5.2 Cost and Accessibility

High-quality PGRs can be expensive, limiting their adoption among smallholder farmers. Developing low-cost, bio-based alternatives and improving distribution systems is crucial.

5.3 Regulatory Framework

In many countries, the use of PGRs is regulated under pesticide or agrochemical laws. Ensuring proper labeling, usage guidelines, and farmer training is essential to safe and effective application.

6. Future Perspectives

As agriculture evolves toward precision and climate-smart models, PGRs are expected to play a more prominent role. Key trends include:

- **Nano-formulations** for controlled hormone release
- **Bio-stimulants** derived from algae, fungi, or bacteria that mimic PGR activity
- **Gene editing** to modulate endogenous hormone pathways
- **Digital platforms** that recommend timing and dosage based on crop monitoring

ISSN (E): 2582 – 7022

Further research into crop-specific responses, synergistic effects with other agro-inputs, and long-term environmental impacts will shape the future of PGR use in sustainable farming.

7. CONCLUSION

Plant growth regulators are powerful tools in the arsenal of modern agronomy. By modulating physiological processes, they enable farmers to improve yields, manage stress, and produce high-quality crops even under challenging conditions. However, their application must be guided by scientific knowledge, proper timing, and integration with broader crop management strategies. With ongoing innovation and responsible usage, PGRs hold significant promise for enhancing agricultural productivity and sustainability.

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