Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 03 (MAY-JUNE, 2026)
Available online at http://www.agriarticles.com

Importance of Plant Growth Regulators in Vegetable Crops

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Plant growth regulators are naturally occurring or synthetic substances that affect specific physiological and biochemical functions in plants, primarily by modulating gene expression and enzyme activity (Olaiya et al., 2013). They are crucial in the development of plant organs such as flowers, stems and leaves as well as in processes like leaf abscission, fruit development and ripening. These regulators also influence plant architecture by controlling seed development, flowering time, floral sex expression, leaf senescence, fruit drop and seed quality. Overall, plant growth regulators have a profound impact on various physiological and biochemical mechanisms governing plant growth and development (Sabagh et al., 2021). The principal groups of plant growth regulators include auxins, gibberellins, cytokinins, ethylene, and abscisic acid along with newer categories such as brassinosteroids, salicylic acid and jasmonates. Their application in vegetable crops has significantly enhanced yield, improved stress resistance and elevated overall crop quality. Moreover, PGRs are widely used to manipulate flowering time, induce parthenocarpy and synchronize crop maturity which are crucial for commercial vegetable cultivation.

Physiological role of PGR's

PGR	Functions
Auxins	Promote cell elongation, root initiation, apical dominance, fruit development, prevent premature fruit drop, inhibition of abscission, parthenocarpy, phototropism, geotropism and regulation of flowering
Gibberellins	Stimulate stem elongation, seed germination, flowering, breaking dormancy, increase fruit size, fruit development and induction of maleness in flowers
Cytokinin	Promote cell division, delay leaf senescence, enhance nutrient mobilization, improve shoot formation bud initiation, chlorophyll retention and enhance post-harvest life
Abscisic Acid	Induces dormancy, regulates stomatal closure, enhances stress tolerance, inhibition of seed germination, mediation of stress responses and inhibits growth under adverse conditions
Ethylene	Regulates fruit ripening, leaf abscission, flower senescence and stress responses

Functional role of PGR's

1. Enhancement of Fruit Set

Low fruit set, particularly in solanaceous vegetables like tomato and brinjal, is a key constraint to yield. The application of auxin-based plant growth regulators such as 4-CPA, 2,4-D (2–5 ppm), and PCPA (50–100 ppm) significantly improves fruit set and early fruit development by imitating natural auxin activity. These substances enhance pollen viability, improve ovary retention, and support successful fruit formation. In tomato, auxin sprays not only increase fruit set but also minimize blossom drop and ensure better fruit uniformity, especially under stress conditions.

2. Seed Germination and Flowering

Plant growth regulators (PGRs) play an important role in regulating flowering and seed germination in vegetable crops. Gibberellins promote early and uniform flowering by inducing floral initiation and bolting in crops like lettuce and cabbage. Auxins and cytokinins help in flower development and improve fruit and seed set. During seed germination, gibberellins break seed dormancy by stimulating enzyme activity that mobilizes stored food reserves. Maleic hydrazide (MH) is used to delay flowering in crops like okra when extended vegetative growth is desired. GA_3 also promotes earlier flowering in leafy vegetables such as lettuce and spinach. Pre-sowing treatments with auxins (IAA, NAA at 20 ppm) or GA_3 (0.5 mg/L) improve seed germination and enhance seedling vigor in crops like okra and tomato.

3. Regulation of Sex Expression

Regulation of sex expression using plant growth regulators is particularly important in crops like cucurbits, okra, and pepper. Application of low concentrations of GA_3 (10–25 ppm), IAA (100 ppm), and NAA (100 ppm) encourages the development of female flowers by increasing ethylene synthesis and altering the hormonal balance within the plant. In contrast, higher doses of GA_3 (1500–2000 ppm) or silver-containing compounds such as silver nitrate and silver thiosulphate (300–400 ppm) inhibit the formation of female flowers and promote male flower production.

4. Inhibition of Sprouting and Dormancy Regulation

Uncontrolled sprouting during storage leads to substantial post-harvest losses in bulb and tuber crops. Plant growth regulators such as maleic hydrazide are widely used to suppress sprouting during storage. Conversely, chemicals like thiourea and gibberellic acid (GA_3) are applied to break dormancy and promote uniform sprouting when required. Application of maleic hydrazide (MH) at 2500 ppm, about two weeks before harvest, effectively inhibits sprouting in stored onion bulbs. In potato, treating tubers with IAA (250–1000 ppm) helps extend dormancy, whereas thiourea (1%) is commonly used to break dormancy and encourage uniform sprouting. Other dormancy-breaking agents such as ethylene chlorhydrin, thiourea, and GA_3 are also effective in crops like potato and lettuce, aiding in off-season cultivation and seed production.

5. Parthenocarpy Induction

Plant growth regulators (PGRs) play a key role in inducing parthenocarpy, the development of fruits without fertilization in many vegetable crops like tomato, cucumber and brinjal. Foliar application of auxins such as IAA, NAA, and synthetic compounds like 2,4-D stimulates ovary growth, leading to seedless fruit formation in crops like tomato, brinjal, and cucumber. Gibberellins (GA_3) are also widely used to induce parthenocarpic fruit set by promoting cell elongation and division in the ovary. This enhances fruit texture, shape and market acceptability.

6. Gametocides and Hybrid Seed Production

Plant growth regulators (PGRs) are widely utilized as gametocides to induce male sterility, which is a crucial step in hybrid seed production of vegetable crops. Male sterility can be artificially achieved through the application of specific PGRs including auxins and anti-auxins such as NAA, TIBA, 2,4-D, maleic hydrazide (MH), gibberellins (GA_3), ethephon and certain chemical compounds (Surwenshi et al., 2019). These substances disrupt normal pollen development leading to controlled sterility and facilitating cross-pollination. For example, MH (100–500 mg/L), GA_3, and 2,3-dichloro-isobutyrate are known to induce selective pollen abortion in crops like okra, pepper and onion. Ethephon application has proven effective in enhancing femaleness and developing female parental lines in cucurbits such as cucumber. Conversely, treatments with GA_3 or silver nitrate (around 500 mg/L) stimulate the production of male flowers in gynoecious cucumber lines, ensuring the availability of pollen for hybridization. The use of PGRs in this way not only simplifies hybrid seed production but also reduces the need for manual emasculation, improves genetic purity and enhances efficiency in large-scale seed production programs.

7. Stress tolerance

Plant growth regulators (PGRs) play a crucial role in enhancing stress tolerance in vegetable crops under adverse environmental conditions. They help plants withstand abiotic stresses such as drought, salinity, extreme temperatures and waterlogging by regulating physiological and biochemical processes. PGRs like abscisic acid improve drought tolerance by inducing stomatal closure and reducing water loss through transpiration. Salicylic acid and jasmonates enhance the plant's defense system by activating stress-responsive genes and antioxidant enzymes. Brassinosteroids promote cell expansion and protect plants from temperature stress by stabilizing membranes and proteins. Cytokinins delay leaf senescence and maintain photosynthetic activity under stress conditions. Auxins improve root growth, enabling better water and nutrient uptake during unfavorable conditions. Gibberellins help in overcoming stress-induced growth inhibition and promote recovery. Additionally, PGRs reduce oxidative damage by enhancing the production of antioxidant compounds. Overall, the use of PGRs strengthens plant resilience, ensuring better growth, yield and productivity of vegetable crops under environmental stress conditions.

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