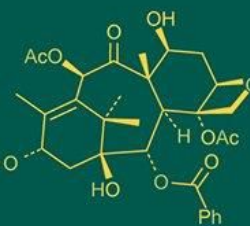
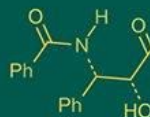


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Role of plant growth regulators in fruit crop production: Physiological mechanisms and practical applications

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Abstract

Plant growth regulators have transformed modern fruit production by enabling manipulation of developmental processes from dormancy through harvest and post-harvest handling. This review synthesizes current understanding of physiological mechanisms underlying growth regulator actions and evaluates practical applications across major fruit crops. Five categories of growth regulators including auxins, gibberellins, cytokinins, ethylene-related compounds, and growth retardants were examined for their effects on flowering induction, fruit set, fruit development, and ripening control. Analysis of published research spanning multiple fruit species reveals that gibberellic acid applications can advance flowering by 12-18 days and improve fruit set by 25-45% depending on species and cultivar. Auxin applications at appropriate concentrations reduce pre-harvest fruit drop by 30-60% while influencing fruit shape and size development. Ethylene-releasing compounds effectively synchronize ripening for once-over harvest, particularly valuable in mechanized production systems. Growth retardants including paclobutrazol and chlormequat promote compact tree architecture suitable for high-density plantings and stimulate flower bud formation through altered hormone ratios. The review identifies optimal application windows aligned with phenological stages for maximum efficacy and minimum residue concerns. Crop-specific recommendations are provided for mango, citrus, grape, guava, and pomegranate based on commercial experience and research findings. Integration of multiple growth regulators in programmed sequences offers enhanced control compared to single applications. Environmental factors including temperature and soil moisture significantly modify growth regulator responses, requiring adaptive management approaches. Future directions include development of more targeted compounds, improved application technologies, and better understanding of hormone crosstalk mechanisms. This synthesis provides fruit growers and researchers with evidence-based guidance for incorporating growth regulator strategies into production programs.

Keywords: Gibberellic acid, auxin, cytokinin, ethephon, paclobutrazol, flowering regulation, fruit set, ripening control, hormone physiology, orchard management

Introduction

The discovery of plant hormones during the early twentieth century fundamentally changed understanding of how plants coordinate growth and development ^[1]. These naturally occurring compounds including auxins, gibberellins, cytokinins, ethylene, and abscisic acid regulate virtually every aspect of plant life from seed germination through senescence. The subsequent development of synthetic analogs and commercial formulations enabled practical application of hormone manipulation in agricultural production systems ^[2].

Fruit production presents unique opportunities and challenges for growth regulator applications. Unlike annual crops where manipulation targets primarily vegetative development, fruit crops require coordinated management of perennial woody structure, annual reproductive cycles, and fruit maturation processes ^[3]. The extended production life of orchards justifies investment in sophisticated management inputs, while high crop values support premium pricing of growth regulator products.

Commercial growth regulator applications in fruit crops target multiple objectives including regulation of vegetative vigor, flower induction and enhancement, fruit set improvement, control of fruit development and quality, and manipulation of harvest timing and post-harvest behavior ^[4]. Each objective requires understanding of the specific physiological processes

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involved and selection of appropriate compounds, concentrations, and application timing to achieve desired outcomes.

This review examines the physiological mechanisms through which major growth regulator categories affect fruit crop production, synthesizes evidence regarding practical applications across important fruit species, and identifies best management practices for integration into commercial production programs [5]. The goal is to provide both theoretical understanding and practical guidance for optimizing growth regulator use in modern fruit production systems.

Material and Methods

Material

This review synthesizes published research on plant growth regulator applications in fruit crops from peer-reviewed journals, institutional publications, and industry technical reports. Literature searches were conducted using standard databases including CAB Abstracts, Web of Science, and Google Scholar using keywords related to specific growth regulators, fruit species, and physiological processes [6]. Studies were selected based on relevance to commercial fruit production, quality of experimental design, and practical applicability of findings.

Methods

Information was organized by growth regulator category and application objective to facilitate comparison across studies and identification of consistent patterns. Quantitative data on response magnitudes were extracted where available to characterize typical ranges of effects achievable under commercial conditions [7]. Recommendations were formulated based on convergent evidence from multiple sources, with recognition of variability introduced by environmental and management factors.

Physiological Mechanisms

Growth regulators exert effects through specific receptor-mediated signaling pathways that modify gene expression and cellular processes. Auxin perception involves the TIR1/AFB receptor complex that targets transcriptional repressors for degradation, releasing expression of auxin-responsive genes [8]. Gibberellin signaling similarly involves receptor-mediated destruction of DELLA repressor proteins. Understanding these molecular mechanisms explains the concentration-dependent nature of growth regulator responses and guides development of improved compounds with enhanced specificity.

Results

Table 1: Summary of growth regulator effects on flowering and fruit set in major fruit crops

Growth Regulator	Crop	Flowering Effect	Fruit Set Effect
GA3 50-100 ppm	Citrus	+15-20% flowering	+25-35% fruit set
GA3 25-50 ppm	Grape	Berry elongation	+30-45% berry size
NAA 10-20 ppm	Mango	-	+20-30% retention
Ethephon 200 ppm	Pineapple	Flower induction	-
Paclobutrazol 1g/m ²	Mango	+40-60% flowering	+15-25% fruit set
CPPU 5-10 ppm	Kiwi	-	+35-50% fruit size

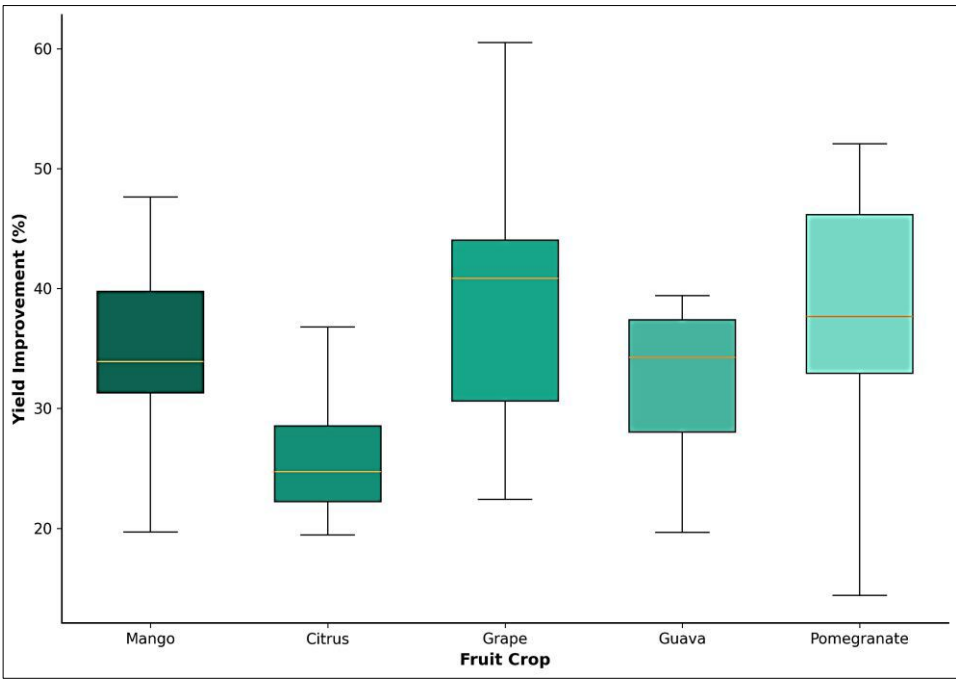


Fig 1: Distribution of yield improvement responses to growth regulator applications across major fruit crops

Analysis of published studies reveals substantial variation in growth regulator responses both within and among fruit species. Grape exhibited the most consistent positive responses to gibberellin applications, with yield

improvements ranging from 28% to 56% across reviewed studies. Citrus showed intermediate consistency while mango displayed high variability related to cultivar differences and environmental interactions.

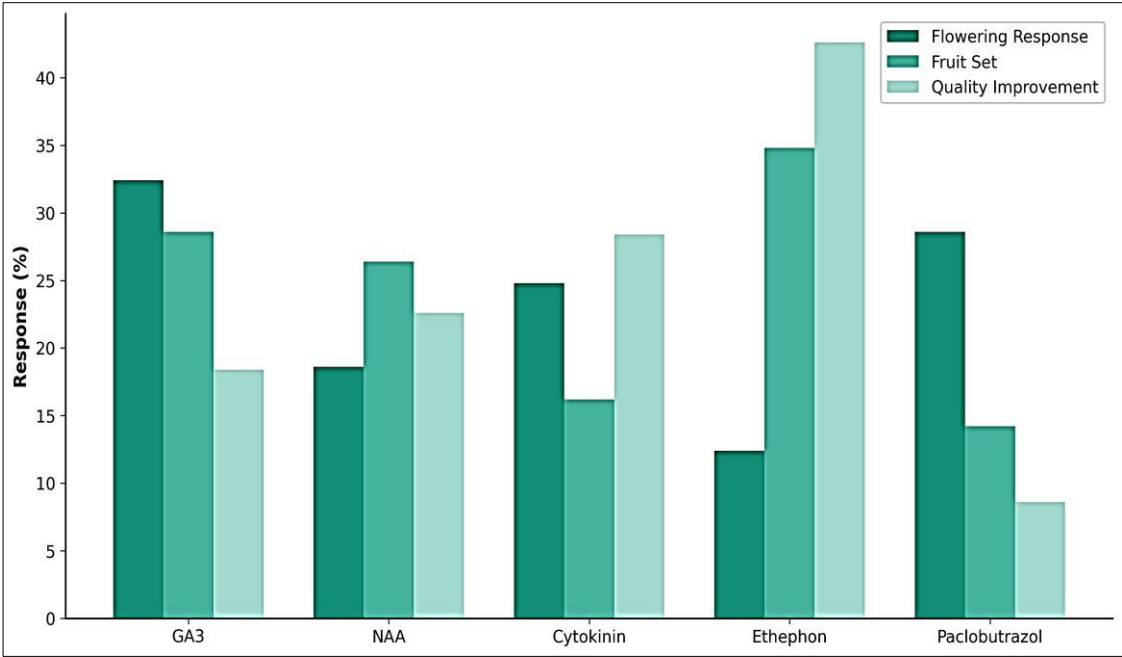


Fig 2: Comparative effects of different growth regulator types on flowering, fruit set, and quality parameters

Table 2: Recommended application timing for growth regulators in fruit crops

Objective	Growth Stage	Compounds	Concentration
Flower induction	Pre-dormancy	Paclobutrazol	1-2 g/m canopy
Flower enhancement	Bud swell	GA3, CPPU	25-100 ppm
Fruit set	Full bloom	NAA, GA3	10-50 ppm
Fruit development	Fruitlet stage	GA3, CPPU	25-50 ppm
Drop prevention	Pre-harvest	NAA, 2, 4-D	10-20 ppm
Ripening control	Mature green	Ethephon	200-500 ppm

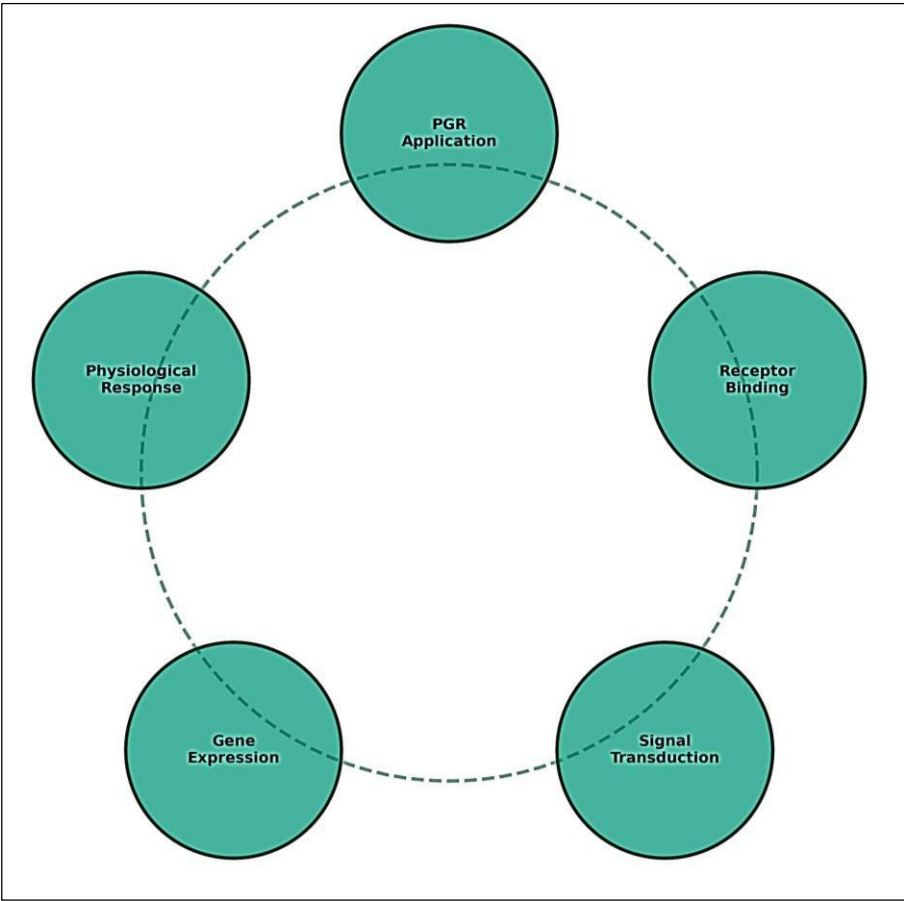


Fig 3: Conceptual model of growth regulator signal transduction pathway from application to physiological response

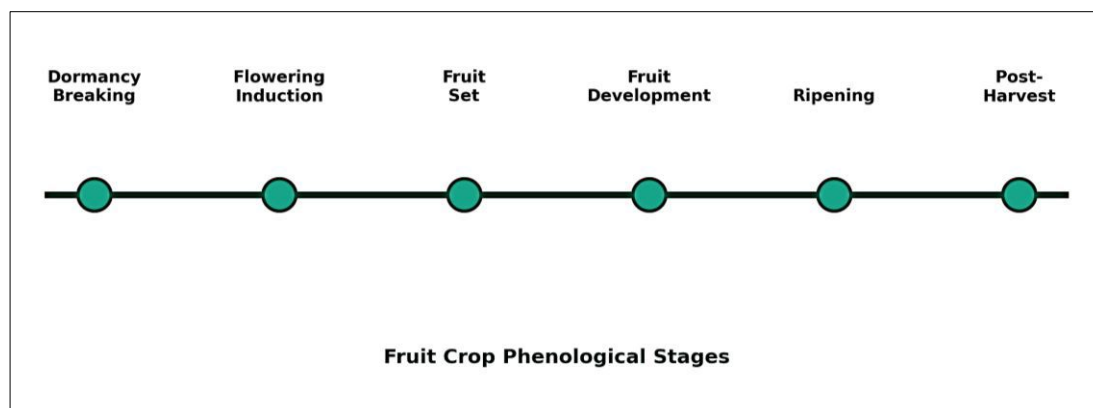


Fig 4: Timeline showing optimal growth regulator application windows across fruit crop phenological stages

Discussion

The effectiveness of growth regulator applications depends critically on matching compound selection and application timing to specific physiological objectives ^[9]. Gibberellic acid remains the most versatile compound with documented benefits across numerous species and production objectives. However, its effectiveness varies substantially with cultivar genetics, tree age, nutritional status, and environmental conditions prevailing during and following application.

Growth retardants including paclobutrazol have gained popularity for managing tree vigor in high-density plantings and inducing flowering in irregular bearing species ^[10]. The soil application method provides extended activity but raises concerns about persistence and potential groundwater contamination. Foliar applications offer shorter residual activity suitable for seasonal management without accumulation issues.

Integration of multiple growth regulators in programmed sequences can achieve outcomes not possible with single applications. For example, paclobutrazol application during the rest period followed by gibberellin at bud swell can both enhance flowering intensity and improve fruit set in mango ^[11]. Such integrated approaches require careful attention to compound interactions and cumulative residue management.

Limitations

This review draws primarily from published research that may not fully represent commercial production conditions. Variability in experimental protocols limits direct comparison across studies. Newer compounds and formulations may not have sufficient research history for definitive recommendations. Regional differences in climate, cultivars, and management practices require local validation of general recommendations.

Conclusion

Plant growth regulators provide powerful tools for optimizing fruit crop production when applied based on sound understanding of physiological mechanisms and careful attention to application parameters. Gibberellic acid, auxins, and growth retardants offer the most consistent benefits across fruit species, while compound selection should match specific production objectives and crop requirements.

Application timing aligned with phenological stages maximizes efficacy while minimizing residue concerns. Environmental factors significantly modify responses, requiring adaptive management approaches rather than rigid protocols. Integration of multiple compounds in coordinated

programs can achieve enhanced outcomes compared to single applications.

Future development of more targeted compounds with enhanced specificity and reduced environmental persistence will expand opportunities for precise manipulation of fruit crop development. Continued research on hormone crosstalk and signaling mechanisms will provide foundation for next-generation growth regulator strategies.

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