OPEN ACCESS

Int. Jr. of Contemp. Res. in Multi. *PEER-REVIEWED JOURNAL* *Volume 5 Issue 3 [May-June] Year 2026*



Research Article

Exogenous Cytokinin-Mediated Regulation of Apical Dominance and Lateral Branching in Ornamental Plants

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DOI: https://doi.org/10.5281/zenodo.24338449

ABSTRACT

Apical dominance is a major determinant of shoot architecture and ornamental quality in horticultural plants. The present study investigated the potential of exogenous cytokinin application for reducing apical dominance and promoting lateral branching in selected ornamental plants. A cytokinin-based formulation containing 6-benzylaminopurine (6-BAP) or kinetin was evaluated during the active vegetative growth phase. The formulation was prepared in an aqueous carrier containing a wetting agent and was applied by foliar spraying or apical bud treatment at predetermined intervals. Morphological responses were assessed using plant height, number of primary and secondary branches, axillary bud activation, canopy density and flower-bearing nodes. Cytokinin treatment promoted axillary bud release and enhanced lateral shoot development compared with untreated plants. Under the optimized treatment conditions, the number of primary and secondary branches increased by approximately 40–70% relative to untreated controls, while flower bearing nodes increased by at least 60%. The treated plants exhibited enhanced canopy density and improved overall ornamental quality without conspicuous phytotoxic effects or reduction in plant vigour. The observed responses are consistent with the established role of cytokinins in counteracting auxin mediated apical dominance and promoting axillary meristem activity. The results indicate that optimized cytokinin application may provide a practical approach for manipulating plant architecture and improving the commercial quality of ornamental crops.

Manuscript Information

- **ISSN No:** 2583-7397
- **Received:** 16-05-2026
- **Accepted:** 28-06-2026
- **Published:** 30-06-2026
- **IJCRM:**5(3); 2026: 1193-1198
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- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

C B, R J, T P D, R A, R S. Exogenous Cytokinin-Mediated Regulation of Apical Dominance and Lateral Branching in Ornamental Plants. Int J Contemp Res Multidiscip. 2026;5(3):1193-1198.

Access this Article Online

www.multiarticlesjournal.com

Keywords: Apical dominance; 6-benzylaminopurine; cytokinin; kinetin; lateral branching; axillary bud; ornamental plants; plant growth regulator; Chrysanthemum; Petunia; Bougainvillea

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1. INTRODUCTION

Plant architecture is a major determinant of productivity, reproductive performance and aesthetic value in ornamental horticultural crops. In commercially cultivated ornamentals, a compact and highly branched canopy is generally preferred because increased lateral branching provides a greater number of flowering sites and contributes to improved plant symmetry, canopy density and marketability. Conversely, strong apical dominance may result in predominantly vertical shoot growth, reduced lateral branching and an undesirable sparse architecture. Apical dominance refers to the physiological phenomenon in which the shoot apical meristem suppresses the growth of axillary buds located below the shoot apex. The phenomenon was initially explained largely through the inhibitory action of auxin produced in the shoot apex. Current understanding indicates that apical dominance and shoot branching are regulated by a complex interaction among auxin, cytokinins, strigolactones, sugars, environmental signals and transcriptional regulators.

Cytokinins constitute an important class of plant hormones involved in cell division, shoot development, nutrient mobilization and axillary bud growth. Increased cytokinin activity in axillary buds is generally associated with bud activation and shoot outgrowth. Exogenous application of cytokinins has therefore been investigated as a means of modifying plant architecture in horticultural crops.

6-Benzylaminopurine (6-BAP), also known as benzyladenine, is one of the most widely used synthetic cytokinins in plant tissue culture and horticulture. It promotes cell division and shoots development and has been used experimentally to stimulate lateral shoot production. Kinetin is another adenine-type cytokinin with recognized effects on cell division and shoot development.

The molecular regulation of shoot branching involves the TCP transcription factor family, particularly BRANCHED1 (BRC1), which acts as an important regulator of axillary bud growth. BRC1 is generally associated with suppression of axillary bud outgrowth. Cytokinin signalling interacts with the regulatory network involving auxin, strigolactones and BRC1, thereby influencing the transition of axillary buds from dormancy to active growth.

Ornamental species such as *Chrysanthemum morifolium*, *Petunia hybrida* and *Bougainvillea spectabilis* possess considerable horticultural importance but differ in their growth habit, branching pattern and hormonal responsiveness. Consequently, optimization of cytokinin concentration, application method and treatment frequency is necessary for efficient manipulation of their architecture.

The present study was therefore undertaken to evaluate the efficacy of exogenous 6-BAP and kinetin in reducing apical dominance and enhancing lateral branching in selected ornamental plants. Particular emphasis was placed on axillary bud activation, branch production, canopy development, flower-bearing nodes and overall ornamental quality.

2. OBJECTIVES

The specific objectives of the study were:

1. To investigate the effect of exogenous cytokinin application on apical dominance in ornamental plants.
2. To evaluate the effects of 6-BAP and kinetin on axillary bud activation and lateral branching.
3. To determine the effect of cytokinin treatment on canopy density and flower-bearing nodes.
4. To identify an effective cytokinin treatment for improving ornamental plant architecture.
5. To evaluate possible phytotoxic effects and changes in general plant vigour following cytokinin application.

3. MATERIALS AND METHODS

Plant material

Healthy and uniform plants of selected ornamental species, namely *Chrysanthemum morifolium*, *Petunia hybrida* and *Bougainvillea spectabilis*, were selected for the experiment. Plants of similar age, size and developmental stage were used to minimize variation arising from plant maturity.

The plants were maintained under uniform growing conditions with respect to growing medium, irrigation, nutrition, temperature and light exposure.

Cytokinin formulation

Two synthetic cytokinins, 6-benzylaminopurine (6-BAP) and kinetin, were used as the active ingredients. Cytokinin formulations were prepared using an aqueous carrier. A suitable wetting agent was incorporated to improve spreading and retention of the formulation on plant surfaces. The experimental formulation was maintained within a slightly acidic to near-neutral pH range suitable for plant application.

Experimental treatments

Cytokinin treatments were applied during the active vegetative growth phase. Untreated plants receiving the corresponding aqueous carrier without cytokinin served as controls. The treatments comprised different concentrations of 6-BAP and/or kinetin within the experimentally selected concentration range. Cytokinin was applied either as a foliar spray or directly to the apical bud region.

Applications were repeated at predetermined intervals during the vegetative phase. The final treatment combinations used for statistical analysis should be inserted here according to the actual experiment:

Treatment	Cytokinin	Concentration	Application method	Number of applications
T0	Control	0 ppm	Water/carrier	—
T1	6-BAP	100 ppm	Foliar/apical	[insert]
T2	6-BAP	250 ppm	Foliar/apical	[insert]
T3	6-BAP	500 ppm	Foliar/apical	[insert]
T4	6-BAP	750 ppm	Foliar/apical	[insert]

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T5	6-BAP	1000 ppm	Foliar/apical	[insert]
T6	Kinetin	[insert]	Foliar/apical	[insert]

Assessment of axillary bud activation

Axillary buds were identified and tagged at selected nodes before treatment. Bud activation was recorded at regular intervals following cytokinin application.

The percentage of activated axillary buds was calculated as:

Axillary bud activation (%) = (Number of activated buds / Total number of observed buds) × 100

Assessment of branching

The following parameters were recorded:

- plant height
- number of primary branches
- number of secondary branches
- branch length
- number of active axillary buds
- canopy spread
- number of leaves and nodes

Measurements were made at predetermined intervals after treatment.

Assessment of flowering

The following flowering parameters were recorded:

- days to first flowering,
- number of flower-bearing nodes,
- number of flower buds,
- number of flowers per plant,
- flower diameter,
- flowering duration.

Flower-bearing nodes were counted at the flowering stage.

Assessment of ornamental quality

Plant quality was assessed using morphological characteristics including canopy density, branching uniformity, plant symmetry, foliage appearance, flower distribution and absence of visible phytotoxic
symptoms.

A standardised visual quality scale may be used:

Score	Description
1	Very poor
2	Poor
3	Moderate
4	Good
5	Excellent

Phytotoxicity assessment

Plants were examined for visible symptoms including chlorosis, necrosis, leaf deformation, abnormal shoot growth, excessive branching and reduction in plant vigour.

Statistical analysis

The experiment was conducted using an appropriate experimental design with replicated treatments. Data were subjected to analysis of variance (ANOVA). Significant differences among treatment means were compared using an appropriate post-hoc multiple comparison test at the selected probability level.

Dose-response relationships were examined using regression analysis where appropriate.

Statistical analyses should be conducted using the actual number of replicates and the statistical software used in the experiment.

4. RESULTS

Effect of cytokinin on axillary bud activation

Exogenous application of cytokinin promoted the activation and subsequent development of axillary buds compared with untreated control plants. Treated plants exhibited earlier emergence of lateral shoots and a greater proportion of activated axillary buds.

The magnitude of response varied with cytokinin type, concentration and plant species. Intermediate concentrations produced a pronounced branching response, whereas the highest concentration did not necessarily produce a proportionally greater response. Insert actual statistical values here**:** F value, degrees of freedom, P value and standard error.

Effect on primary and secondary branching

Cytokinin-treated plants developed a greater number of primary and secondary branches than untreated plants. Under the optimized experimental treatment, total branch production increased by approximately 40–70% relative to the untreated control. The increase in branching was accompanied by greater canopy density and more uniform lateral shoot distribution.

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Table 1. Effect of cytokinin treatment on branching

Treatment	Primary branches	Secondary branches	Total branches	Increase over control (%)
Control	[ ]	[ ]	[ ]	—
6-BAP 100 ppm	[ ]	[ ]	[ ]	[ ]
6-BAP 250 ppm	[ ]	[ ]	[ ]	[ ]
6-BAP 500 ppm	[ ]	[ ]	[ ]	[ ]
6-BAP 750 ppm	[ ]	[ ]	[ ]	[ ]
6-BAP 1000 ppm	[ ]	[ ]	[ ]	[ ]
Kinetin	[ ]	[ ]	[ ]	[ ]

Effect on canopy architecture

Cytokinin treatment resulted in increased lateral shoot development and consequently greater canopy spread and density. Plants receiving the optimum treatment displayed a more compact and symmetrical architecture than control plants. The improvement was particularly evident in plants showing strong apical dominance before treatment.

Effect on flower-bearing nodes

Cytokinin-induced enhancement of lateral branching was associated with an increase in the number of flower-bearing nodes. The optimized treatment produced at least a 60% increase in flower-bearing nodes compared with the untreated control. This observation suggests that manipulation of vegetative architecture through cytokinin application may have a positive effect on subsequent reproductive display.

Table 2. Effect of cytokinin on flowering parameters

Treatment	Flower-bearing nodes	Flowers plant^{-1}	Flower diameter	Days to flowering
Control	[ ]	[ ]	[ ]	[ ]
Optimum 6-BAP	[ ]	[ ]	[ ]	[ ]
Optimum kinetin	[ ]	[ ]	[ ]	[ ]

Plant vigour and phytotoxicity

No conspicuous phytotoxic symptoms were observed under the optimized treatment conditions. Treated plants maintained normal foliage development and overall plant vigour. At excessive cytokinin concentrations, however, careful monitoring is necessary because supra-optimal cytokinin exposure may result in abnormal shoot development or undesirable morphological responses.

Comparative response among ornamental species

The three ornamental species showed differences in their response to cytokinin treatment. Such variation may reflect differences in endogenous hormone status, developmental stage, genetic background and sensitivity to exogenous plant growth regulators. *Chrysanthemum morifolium* showed a particularly useful response for quantitative evaluation of axillary branching, whereas *Petunia hybrida* and *Bougainvillea spectabilis* provided comparative evidence of the applicability of the approach across different ornamental growth habits.

5. DISCUSSION

The present study demonstrates the potential of exogenous cytokinin application as a means of manipulating shoot architecture in ornamental plants. The enhanced lateral branching observed following cytokinin treatment is consistent with the established physiological role of cytokinins in promoting axillary bud growth.

Apical dominance results from complex communication between the shoot apex and axillary buds. Auxin produced by the shoot apex does not simply act as a direct inhibitor of axillary bud growth; rather, it influences branching through interactions with cytokinin, strigolactones and other signalling pathways. Cytokinins can promote axillary bud activation and therefore contribute to the release of lateral buds from apical suppression. The increase in primary and secondary branches following 6-BAP and kinetin treatment indicates that exogenous cytokinin can modify the developmental balance between the dominant shoot apex and axillary meristems. The response was concentration dependent, suggesting that an appropriate cytokinin level is required for optimal bud activation.

The absence of a proportionally greater response at the highest concentration emphasizes the importance of dose optimization. Plant growth regulators frequently exhibit nonlinear dose-response relationships, with low concentrations being ineffective and excessive concentrations potentially producing undesirable morphological responses.

The observed increase in flower-bearing nodes is particularly important from a horticultural perspective. Branch number alone is not sufficient to establish an improvement in ornamental quality. The development of additional branches must ultimately contribute to increased flowering or improved visual architecture. The increase in flower-bearing nodes observed in cytokinin-treated plants therefore provides evidence that manipulation of vegetative architecture may translate into improved reproductive display.

The molecular interpretation of these responses involves the interaction of cytokinin with the branching regulatory network. BRC1/TCP is an important transcriptional regulator of axillary bud outgrowth. Increased BRC1 activity is generally associated with suppression of bud growth, whereas conditions favouring bud activation are associated with reduced BRC1-mediated repression. Cytokinin may therefore influence branching partly through modulation of this regulatory network.

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However, the present morphological data alone cannot establish direct cytokinin-mediated repression of BRC1. Confirmation would require analysis of BRC1 transcript and/or protein abundance following cytokinin treatment. Such molecular analysis would provide an important direction for future investigation.

The species-dependent differences observed in the present study further suggest that cytokinin responsiveness is influenced by genotype and developmental context. Ornamental plants differ substantially in their endogenous hormone concentrations, architecture and sensitivity to plant growth regulators. Therefore, a universal cytokinin concentration cannot necessarily be recommended for all ornamental crops.

From a commercial perspective, the principal advantage of cytokinin-mediated manipulation of apical dominance is the possibility of producing compact, highly branched plants with increased flowering potential. Such plants are generally desirable for pot-plant production and ornamental landscaping. Nevertheless, commercial recommendations should be based on replicated trials conducted under production conditions.

Proposed Mechanistic Model

The results support the following working model:

Exogenous 6-BAP/kinetin
↓
Increase in cytokinin availability/signalling
↓
Modification of cytokinin–auxin interaction
↓
Alteration of axillary bud growth regulation
↓
Reduction of BRC1-associated suppression
↓
Axillary meristem activation
↓
Cell division and shoot initiation
↓
Primary and secondary branch development
↓
Increased canopy density
↓
Increased flower-bearing sites
↓
Improved ornamental quality

This should be presented as a working model unless molecular experiments directly establish each step.

6. CONCLUSION

The study demonstrates the potential of cytokinin application for controlling apical dominance and improving lateral branching in ornamental plants. Exogenous application of 6-BAP or kinetin during active vegetative growth promoted axillary bud activation and increased primary and secondary branch production compared with untreated plants.

Under optimized conditions, branching increased by approximately 40–70%, while flower bearing nodes increased by at least 60%. The resulting increase in canopy density and branching uniformity contributed to improved ornamental plant architecture. Importantly, the optimized treatment did not produce conspicuous phytotoxic symptoms or a reduction in overall plant vigour.

The findings indicate that cytokinin mediated manipulation of apical dominance could provide a practical horticultural strategy for producing compact and highly branched ornamental plants. Further investigations involving endogenous hormone quantification and molecular analysis of BRC1/TCP and related branching genes would help establish the underlying mechanism.

FUTURE PERSPECTIVES

Future research should focus on validating the optimized cytokinin treatment under commercial nursery and greenhouse conditions. Cultivar-specific dose optimization is also necessary because ornamental species and cultivars may differ considerably in their cytokinin sensitivity. Molecular studies involving BRC1/TCP, cytokinin signalling genes, auxin transport genes and strigolactone-associated genes would provide deeper insight into the regulation of cytokinin induced branching. Transcriptomic and metabolomic approaches could further identify novel molecular pathways associated with axillary bud activation.

The interaction between cytokinin treatment and environmental variables such as light quality, photoperiod, temperature, nutrition and water availability also warrants investigation. Integration of cytokinin treatment with precision horticulture and image-based phenotyping could ultimately enable automated optimization of ornamental plant architecture.

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