Plant Archives Vol. 26, No. 1, 2026 pp. 1483-1489 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.204

INFLUENCE OF PLANT DENSITY AND PLANT GROWTH REGULATORS ON POT PRESENTABILITY OF *ZINNIA ELEGANS* JACQ.

A Monika Sri Nagini[1], Rajasekhar Marri[2*], K Kaladhar Babu[3], G Jyothi[4] and P Gouthami[5]

[1]Department of Floriculture and Landscape Architecture, College of Horticulture, Mojerla, Dist.- Wanaparthy, Telangana State – 509382, India

[2]Sri Konda Laxman Telangana State Horticultural University, Mulugu. Dist.- Siddipet – 502279, Telangana, India

[3]Department of Floriculture and Landscape Architecture, College of Horticulture, Rajendranagar, Hyderabad – 500030, Telangana, India

[4]Floricultural Research Station - Rajendranagar, Hyderabad – 500030, Telangana, India

[5]Department of Crop Physiology, College of Horticulture, Mojerla, Dist.- Wanaparthy, Telangana, India

*Corresponding author E-mail: rajasmarri@gmail.com

(Date of Receiving : 14-01-2026; Date of Revision : 06-03-2026; Date of Acceptance : 27-03-2026)

ABSTRACT

An experiment was conducted under polyhouse conditions at the College of Horticulture, Mojerla, from December 2022 to March 2023 to evaluate the influence of plant density and plant growth regulators on pot presentability of *Zinnia elegans* Jacq. The study was laid out in a Factorial Completely Randomized Design with two plant densities (three and four plants per pot) and seven growth regulator treatments with different concentrations of cycocel and paclobutrazol. Results revealed that four plants per pot significantly enhanced the total pot presentability score (87.22) compared to three plants (78.45). Among growth regulators, cycocel @ 1500 ppm recorded the highest total score (89.52), while control showed the lowest (73.70). The interaction treatment of four plants per pot + cycocel @ 1500 ppm (P_2R_2) produced maximum overall pot presentability (97.30) with superior flowering and plant architecture traits. The findings demonstrate that optimised plant density, combined with appropriate application of growth regulators, can significantly enhance the aesthetic quality, market value and production efficiency of potted zinnia. This approach may improve the profitability and commercial viability of ornamental pot plant production.

Keywords **:** Anti-gibberellins, Cycocel, Paclobutrazol, Plant density, Zinnia.

Introduction

Zinnia elegans Jacq., belonging to the family Asteraceae, is one of the most popular annual ornamental flowering plants cultivated for garden display and pot culture. The genus *Zinnia* comprises nearly 20 species of annuals and perennials, of which *Z. elegans* (syn. *Zinnia violacea*) is the most widely cultivated due to its wide range of vibrant colours, sturdy peduncles, profuse flowering habit and extended vase life. Native to Mexico and parts of Central and South America, zinnia has gained considerable commercial importance in ornamental horticulture owing to its adaptability and ease of cultivation.

With rapid urbanization, diminishing open spaces and changing lifestyle patterns, the demand for ornamental potted plants has increased significantly in India. Potted ornamentals serve as cost-effective decorative elements for balconies, terraces, indoor spaces and urban landscapes. Under such production systems, pot presentability characterized by compact plant stature, symmetrical canopy, uniform height, optimal plant spread and profuse, well-distributed flowering has emerged as a key determinant of consumer preference and market acceptability. Therefore, production of aesthetically appealing, compact and floriferous plants is a primary objective in commercial pot plant cultivation.

Plant density plays a crucial role in determining canopy fullness, visual symmetry and overall attractiveness of potted plants. An optimum number of plants per pot ensures balanced growth and improved ornamental value. In contrast, overcrowding may lead

to competition for nutrients, light, and moisture, adversely affecting plant vigour and flower quality. Similarly, excessive vegetative growth and stem elongation can reduce compactness and diminish the aesthetic appeal of potted plants.

Plant growth retardants are widely employed in ornamental horticulture to regulate plant height and improve plant architecture. Chlormequat chloride (Cycocel), a quaternary ammonium compound, inhibits gibberellin biosynthesis and restricts stem elongation (Taiz and Zeiger, 2006; Megersa *et al.*, 2018). Paclobutrazol has also been reported to effectively suppress shoot growth, enhance branching, improve foliage colour and promote uniform flowering (Lever *et al.*, 1982; Menhenett and Hanks, 1982; Karimi *et al.*, 2020). Although several studies have documented the influence of growth regulators on growth and flowering of zinnia, systematic information on the combined effect of plant density and growth regulator treatments on pot presentability parameters under Indian conditions remains limited. Most previous investigations have focused primarily on field performance or individual growth responses rather than integrated evaluation of aesthetic and marketable traits in pot culture.

In view of the increasing demand for high-quality potted ornamentals and the limited available information on optimizing plant density in conjunction with growth regulator application, the present investigation was undertaken to evaluate the efficacy of different plant densities and growth regulators on growth, flowering behaviour and pot presentability of potted annual *Zinnia elegans*.

Material and Methods

The present investigation was carried out under polyhouse conditions at the Floriculture Block, College of Horticulture, Mojerla, Wanaparthy district. The experimental site falls under semi-arid tropical climate located at an altitude of 360 m above mean sea level, 17° 19′ North latitude and 78° 29′ East longitude. The study was designed as a Factorial Completely Randomised Design (FCRD) with two replications, comprising two factors. The first factor consisted of two plant density levels: P_1 (three plants per pot) and P_2 (four plants per pot). The second factor included seven levels of growth regulators: R_0 (no spray), R_1 (Cycocel @ 1000 ppm), R_2 (Cycocel @ 1500 ppm), R_3 (Cycocel @ 2000 ppm), R_4 (Paclobutrazol @ 60 ppm), R_5 (Paclobutrazol @ 90 ppm) and R_6 (Paclobutrazol @ 120 ppm).

Seeds were sown in plug trays filled with a mixture of cocopeat and vermicompost. Twenty-one days after sowing, uniform and healthy seedlings were transplanted into pots containing a potting mixture of red earth, vermicompost, farmyard manure (FYM), and cocopeat in a 1:1:1:1 ratio. The first application of growth regulators was made at the 3-4 leaf stage, followed by a second spray 25 days later. Uniform cultural practices, such as irrigation, weeding, and plant protection measures, were carried out in accordance with standard recommendations throughout the experimental period. Observations were recorded to evaluate the influence of plant density and growth regulator treatments on pot presentability parameters based on the score chart and the mean data recorded were subjected to analysis of variance using FCRD, as explained by Panse and Sukhatme (1985).

Pot presentability (Score)

Pot presentability was evaluated on the basis of a scoring system developed by Conover (1986) with slight modifications. The parameters, *viz*., plant shape and flowering, were studied, and points were allotted to each parameter out of a maximum of 100, as described in Table 1.

Table 1 : Pot presentability score chart (Conover, 1986)

S. No.	Parameters	Maximum Points	Description	Score
	A) Flowering			
1	Number offlowers per pot	20	>20 flowers per pot	20
			20-15 flowers per plant	17
			10-15 flowers per plant	18
			5-10 flowers per plant	16
			< 5 flowers per plant	10
2	Flower size (cm)	10	2.0- 4.0 cm	10
			4.0-6.0 cm	10
			6.0 -8.0 cm	0
			8.0-10.0 cm	0
3	Colour	10	Flower with clear colour no fading and no residue.	10
			Slight fading and dull colour	6
			Very dull and faded	4

	B) Shape			
4	Stem and foliage	20	Plant self-supportive with very strong stems having healthy foliage and free ofany infestation and bruises	20
			Plants less supportive with relativelyless strong stems, foliage somewhat healthy and having little pests , disease infestation and bruises	17
			Plant not self-supportive, having lessstrong stems with unhealthy foliage and considerable infestation of pests, diseases and bruises	12
	C) Form			
5	Plant height	10	Plants in balance with pot are neither tootall, nor too small, generally 2.5 times to the height of the pot	8
			Plants too large or too small to the height of the pot	6
6	Plant spread	10	Plant spread in balance with pot, neithertoo large nor too small, generally equalto the height of the plant	10
			Plant spread too large or small to the height of the plant	7
7	Plant Appearance as awhole plant	20	Fresh appearance, no indication of senescence, mechanical and insect damage in flowers/ stems/shoots/foliage	18
			Fresh appearance but slight indication of senescence	17
			Dull appearance and considerable indication of senescence	9
	Total Score	**100**		

Results and Discussion

Number of flowers per pot

Table 2 reveals that the maximum score for the number of flowers per pot (18.27) was recorded at a plant density of four plants per pot. Pandey *et al*. (2014) also observed more number of flowers per plant at higher plant density in marigold.

Among different concentrations of growth regulators highest score for the number of flowers per pot (18.50) was recorded with cycocel at 1500 ppm. Whereas, the lowest score for number of flowers per pot (16.48) was recorded in control (no spray). It is a well-known fact that cycocel played a major role in the suppression of apical dominance, which resulted in increased biometric characteristics like more branches and leaves which might have resulted in production and accumulation of more photosynthates that were diverted to the sink (flower) resulting in more number of flowers with better weight and ultimately the yield (Mohd Ahmed *et al.*, 1988).

Among interaction effects of plant density and different concentrations of growth regulators, the maximum score for number of flowers per pot (20.00) were observed with the treatment combination of P_2 R_2 (Four plants per pot + Cycocel at 1500 ppm).

Table 2 : Effect of plant density and growth regulators on score of number of flowers per pot in zinnia.

Growth regulators	Plant Density		
	P_1	P_2	Mean
R_0	14.55	18.42	16.48
R_1	16.05	17.95	17.00
R_2	17.00	20.00	18.50
R_3	15.75	17.90	16.82
R_4	16.67	17.20	16.93
R_5	17.90	18.20	18.05
R_6	15.65	18.25	16.95
Mean	16.22	18.27	
	S.E.M		C.D.5%
P	0.10		0.33
R	0.20		0.62
P*R	0.28		0.87

Flower size

The effect of different plant densities on score of flower size was found to be statistically significant. The highest score for flower size was recorded at plant density of four plants per pot (8.90)

Among growth regulators maximum score for flower size (9.27) was recorded with cycocel at 1500 ppm while the minimum score for flower size (7.77) was noticed in control (No spray). Among interaction effects of plant density and different concentrations of

growth regulators, the maximum score for flower size (9.70) were observed with the treatment combination of P_2 R_2 (Four plants per pot + Cycocel at 1500 ppm). The reduction in flower diameter observed under cycocel and paclobutrazol treatments may be attributed primarily to the inhibition of gibberellin biosynthesis. Both compounds act as growth retardants by blocking key steps in the gibberellin pathway, thereby restricting cell elongation and expansion (Rademacher, 2000). El-Sharhorey *et al*. (2022) reported that flowers with less diameter were produced in plants treated with cycocel and paclobutrazol in zinnia (Figure 1).

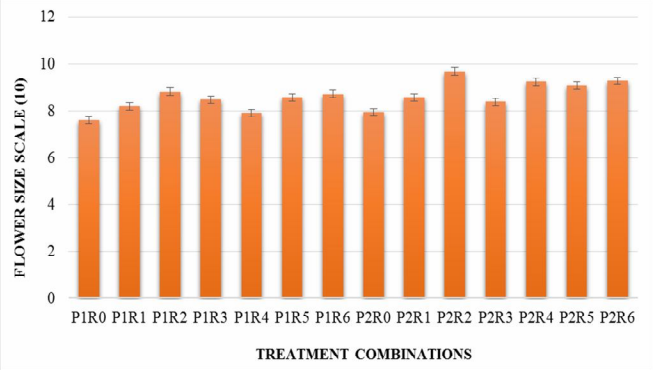

Fig. 1 : Effect of plant density and growth regulators on score of flower size in zinnia.

Flower Colour

Table 3 reveals that the highest score for flower colour (8.37) was recorded at a plant density of four plants per pot.

Among different concentrations of growth regulators highest score for flower colour (8.85) was recorded with cycocel at 1500 ppm. Whereas, the lowest score for number of flowers per pot (7.25) was recorded in control (no spray). Among interaction effects of plant density and different concentrations of growth regulators, the maximum score for flower colour (9.40) was observed with the treatment combination of P_2 R_2 (Four plants per pot + Cycocel at 1500 ppm).

This may be due to the effect of growth retardants which may increase endogenous cytokinin levels and antioxidant enzyme activity, thereby stabilising pigment molecules and enhancing colour clarity (Taiz and Zeiger, 2006).

Table 3 : Effect of plant density and growth regulators on score of flower colour in zinnia.

Growth Regulators	Plant Density		
	P_1	P_2	Mean
R_0	7.10	7.40	7.25
R_1	7.70	7.70	7.70
R_2	7.60	9.40	8.50
R_3	8.00	8.40	8.20
R_4	8.30	7.90	8.10
R_5	9.00	8.70	8.85
R_6	7.60	9.10	8.35
Mean	7.90	8.37	
	S.E.M		C.D.5%
P	0.11		0.35
R	0.21		0.66
P*R	0.30		0.93

Stem and foliage

The effect of different plant densities on score of stem and foliage was found to be statistically significant. The highest score for flower size was recorded at plant density of four plants per pot (18.14) (Figure 2).

Among growth regulators, the maximum score for stem and foliage (18.47) was recorded with cycocel at 1500 ppm, whereas the minimum score (16.00) was observed in the control (no spray). Among the interaction effects of plant density and different concentrations of growth regulators, the maximum score for stem and foliage (20.00) was observed with the treatment combination of P_2 R_2 (Four plants per pot + Cycocel at 1500 ppm). Plants treated with cycocel and paclobutrazol developed self-supportive structures with strong stems due to inhibited gibberellin biosynthesis, leading to shorter internodes, thicker cell walls, and increased vascular bundles. These regulators promote compact growth, higher chlorophyll content, and denser foliage, enhancing overall plant vigour under stress conditions (Kumar *et al.*, 2022).

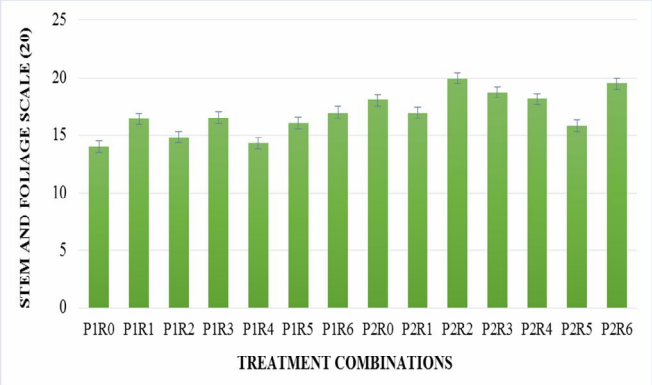

Fig. 2 : Effect of plant density and growth regulators on score of stem and foliage in zinnia.

Plant height

From Table 4, it is evident that the highest score for plant height was recorded with plant density of four plants per pot (8.91) while plant density at three plants per pot recorded less score for plant height (8.34).

Among growth regulators maximum score for plant height (9.40) was recorded with cycocel at 15000 ppm, while the minimum score for height (7.70) was

noticed in control (No spray). Among the interaction effects of plant density and different concentrations of growth regulators, the maximum score for plant height (10.00) was observed with the treatment combination of P_2 R_2 (Four plants per pot + Cycocel at 1500 ppm).

Availability of more amount of nutrients, space, sunlight and moisture at lower plant densities result in luxuriant and vigorous growth of the plants. The results are in accordance with Rezazadeh *et al*. (2015) who reported minimum plant height in purple fire spike at lower plant density. Accordingly, the reduction in plant height might be due to the retardation of cell elongation, particularly in stellar cambium which is the zone of the meristematic activity at the base of the internodes (Grossman, 1992; Fisher *et al*., 1996 and Karunananda and Peiris., 2010). Reduction in plant height in *Calendula officinalis* upon treatment with cycocel was reported by Hashemabadi *et al*. (2012).

Table 4 : Effect of plant density and growth regulators on score of plant height in zinnia.

Growth Regulators	Plant Density		
	P_1	P_2	Mean
R_0	7.60	7.80	7.70
R_1	8.00	8.10	8.05
R_2	8.80	10.00	9.40
R_3	8.50	9.20	8.85
R_4	8.40	8.30	8.35
R_5	8.00	9.40	8.70
R_6	9.10	9.60	9.35
Mean	8.34	8.91	
	S.E.M		C.D.5%
P	0.08		0.24
R	0.15		0.45
P*R	0.21		0.65

Plant spread

The maximum score for plant height was recorded with plant density of four plants per pot (8.61) while plant density at three plants per pot recorded less score for plant height (8.35) (Table 5).

Among growth regulators maximum score for plant spread (9.30) was recorded with cycocel at 1500 ppm, while the minimum score for height (7.15) was noticed in control (No spray). Among the interaction effects of plant density and different concentrations of growth regulators, the maximum score for plant height (9.70) was observed with the treatment combination of P_2 R_2 (Four plants per pot + Cycocel at 1500 ppm).

Higher plant density resulted in maximum plant spread in both East-West and North-South directions. It might be due to increased number of branches and decreased plant height that covered the whole pot. Plant spread is one of the most essential characters of potted plants which makes them look bushy with the size of the pot. The increased plant spread both in East-West and North-South directions might be due to the inhibition of apical dominance by cycocel which results in the production of a greater number of branches. Singh *et al*., (2018) recorded maximum plant spread in chrysanthemum treated with cycocel, similarly, higher plant spread both in East-West and North-South directions was recorded by Patel *et al*., (2022) in bougainvillea in plants treated with cycocel.

Table 5 : Effect of plant density and growth regulators on score of plant spread in zinnia.

Growth Regulators	Plant Density		
	P_1	P_2	Mean
R_0	7.00	7.30	7.15
R_1	8.40	8.40	8.40
R_2	8.90	9.70	9.30
R_3	8.70	9.40	9.05
R_4	8.60	7.50	8.05
R_5	7.90	9.70	8.80
R_6	9.00	8.20	8.60
Mean	8.35	8.61	
	S.E.M		C.D.5%
P	0.05		0.16
R	0.10		0.31
P*R	0.14		0.44

Plant Appearance as a whole plant

Table 6 reveals that the highest score for plant appearance as a whole plant was observed at higher plant density, i.e., four plants per pot (16.22), while the lowest score was recorded at lower plant density (14.07).

Among different concentrations of growth regulators highest score for whole plant appearance (18.00) was recorded with cycocel at 1500 ppm. Whereas, the lowest score for number of flowers per pot (11.75) was recorded in control (no spray). Among interaction effects of plant density and different concentrations of growth regulators, the maximum score for whole appearance (20.00) was observed with the treatment combination of P_2 R_2 (Four plants per pot + Cycocel at 1500 ppm).

Table 6 : Effect of plant density and growth regulators on score of plant appearance as whole plant in zinnia.

Growth Regulators	Plant Density		
	P_1	P_2	MEAN
R_0	11.50	12.00	11.75
R_1	12.60	13.60	13.10
R_2	16.00	20.00	18.00
R_3	15.40	16.80	16.10
R_4	15.00	15.00	15.00

R_5	13.80	17.20	15.50
R_6	14.20	19.00	16.60
MEAN	14.07	16.22	
	S.E.M		**C.D.5%**
P	0.27		0.84
R	0.51		1.58
P*R	0.73		2.24

From Figure 3 it is observed that the maximum score for total pot presentability was recorded in pots with four plants (87.22), while the minimum score total pot presentability was recorded in pots with three plants (78.45).

Among different concentrations of growth regulators highest score for total pot presentability (89.52) was recorded with cycocel at 1500 ppm. Whereas, the lowest score for number of flowers per pot (73.70) was recorded in control (no spray). Among interaction effects of plant density and different concentrations of growth regulators, the maximum score for whole appearance (97.30) was observed with the treatment combination of P_2 R_2 (Four plants per pot + Cycocel at 1500 ppm).

Pot presentability was highest in pots containing four plants per pot and treated with cycocel at 1500 ppm as they produced a greater number of flowers per plants, lesser plant height with strong supportive stems, more number of branches which gives them a bushy appearance and foliage and flowers with no bruises and with no infestation of pests and diseases.

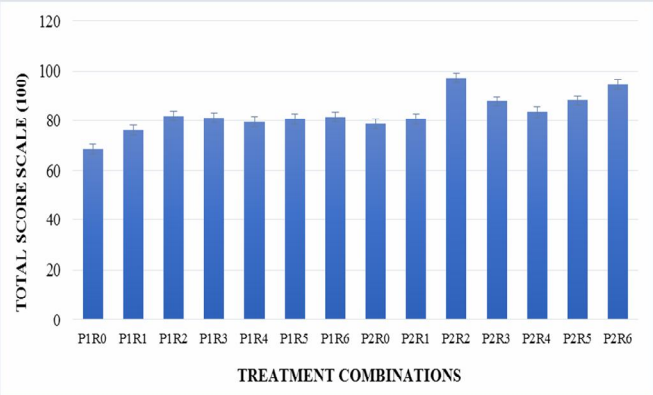

Fig. 3 : Effect of plant density and growth regulators on total pot presentability score in zinnia

Conclusion

It can be interpreted from the experimental results that, plant density and growth regulator treatments significantly influenced pot presentability of *Zinnia elegans*. Pots with four plants recorded a higher total presentability score (87.22) compared to three plants per pot (78.45). Among growth regulators, cycocel @ 1500 ppm achieved the maximum total score (89.52), whereas control recorded the lowest (73.70). The interaction treatment P_2R_2 (four plants per pot + cycocel @ 1500 ppm) produced the highest overall pot presentability score (97.30), along with maximum scores for number of flowers (20.00), flower size (9.70), flower colour (9.40), stem and foliage (20.00), plant height (10.00), plant spread (9.70), and whole plant appearance (20.00). In contrast, P_1R_3 (three plants per pot + cycocel @ 2000 ppm) delayed flowering. Therefore, four plants per pot combined with cycocel @ 1500 ppm was found most effective for enhancing flower yield, quality, and overall aesthetic value and thus helps in the commercial production of potted annual zinnia.

Acknowledgements

The author is grateful to the Department of Floriculture and Landscaping, College of Horticulture, Mojerla, SKLTSHU, for providing the necessary facilities to conduct this study for her Master's programme.

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