



Plant Archives

Journal homepage: <http://www.plantarchives.org>

DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.140>

ASSESSMENT OF TINTING-INDUCED PHYSIOLOGICAL AND MORPHOLOGICAL CHANGES IN *DIANTHUS CARYOPHYLLUS* FLOWER DURING VASE LIFE

Milu Nalwa N.^{1*}, Kunal Adhikary², Abhirami A.¹, Vishnupriya K. V.¹, Nafees Khan³ and Sahim Khan³

¹Department of Floriculture and Landscaping, School of Agricultural Sciences, GD Goenka University, Sohna Road, Gurugram-Haryana, India

²Department of Agronomy, School of Agricultural Sciences, GD Goenka University, Sohna Road, Gurugram-Haryana, India

*Corresponding author E-mail: milunalwa451@gmail.com

(Date of Receiving : 09-12-2025; Date of Revision : 29-01-2026; Date of Acceptance : 22-02-2026)

ABSTRACT

This study used a two-factor completely randomized design to assess the physiological and visual reactions of cut carnation (*Dianthus caryophyllus*) flowers after tinting with six dye colors (green, blue, red, yellow, pink and black) at two concentrations (5% and 10%). All studied parameters, including flower weight, dye uptake, degradation, tinting duration and sensory quality, showed significant impacts of color, concentration and their interaction. The largest biomass, maximum dye absorption, least degradation, and best sensory acceptance were obtained with green dye, especially at 10%. Blue dye came in second. Darker hues showed worse visual quality, more degradation, and slower absorption. Overall, the results show that vascular mobility, osmotic balance, and postharvest performance are significantly influenced by dye properties, with green 10% showing up as the most effective tinting treatment.

Keywords : Carnation, Food dyes, Pigment absorption, Xylem transport, Flower deterioration & Vase longevity.

Introduction

Carnations (*Dianthus caryophyllus* L.; fam. Caryophyllaceae), Native to Southern Europe and the Mediterranean region, are perennial blooming plants with a variety of colours that are semi-hardy (Mebakerlin *et al.*, 2015). Inflorescence is typically a terminal cyme since each carnation stalk produces a terminal flower (Heikal *et al.*, 2023). In the floriculture sector, tinting has grown in popularity as a way to improve or alter the natural color of carnations, allowing growers to satisfy consumer demand for distinctive and theme-specific floral goods (Sowmeya *et al.*, 2017). Sarhan *et al.* (2023) point out that despite tinting's extensive commercial use little is known about its physiological and structural consequences on carnation blooms (Gupta *et al.*, 2022 & Faust *et al.*, 2024) The use of food-grade dyes in various hues and concentrations provides a controlled and safe way to investigate how pigment absorption affects hydration, osmotic balance, light interaction, and general

postharvest behaviour (Aalifar *et al.*, 2020). Quantitative measurements of color intensity, absorbance, and reflectance provide more information about how tinting affects metabolic activity and tissue integrity (Pace *et al.*, 2022; Zhang *et al.*, 2021). To improve postharvest handling, decorative value, and colour enhancement techniques (Vijay *et al.*, 2025), this study aims to investigate the effects of various tint colours and concentrations on the physiological, structural, and aesthetic characteristics of carnation flowers during vase life. Floriculture has become a vibrant and rapidly expanding branch of modern horticulture due to the growth of online floral markets, shifting urban lifestyles, and the rising desire for decorative plants globally. Jawaharlal *et al.* (2009) the global floriculture industry is expected to grow steadily as both developed and emerging economies engage in state-of-the-art production technologies and ecologically friendly agricultural practices, with a projected value of over USD 52 billion in 2023. The

international flower trade is dominated by large exporters such as Ethiopia, Kenya, Colombia, and the Netherlands, a pattern frequently documented in global floriculture analysis (Gebremedhin, 2020; Zeiri *et al.*, 2021). Emerging economies such as Vietnam and India are rapidly improving their market positions through technical breakthroughs and supportive policy interventions (Hossain & Islam, 2022). According to Singh and Kumar (2023), major commercial flowers, such as roses, gerberas, tuberose, and carnations, significantly contribute to local and foreign markets, rural employment, and agricultural GDP in India (Sneha *et al.*, 2019). Additionally, government initiatives and national horticultural missions have

greatly accelerated the growth of the floriculture industry nationwide (NHB, 2022).

Materials and Methods

The investigation was carried out at the GD Goenka University Horticultural Laboratory in Sohna, Haryana (~200 m AMSL; 28.24°N, 77.07°E) (Table 1). Hot summers, moderate monsoons, and mild winters characterise the subtropical climate of the area. The average relative humidity for the experiment was almost 70%, and the temperature ranged from 28 to 33°C. The lab provided a controlled setting that was appropriate for precisely evaluating the physiological and quality parameters of carnation flower under various vase solution treatments.

Table 1: Overview of Experimental Material, Factors, and Treatment Combinations

Particulars	Details
Experimental material	Carnation (<i>Dianthus caryophyllus</i>)
Experimental design	2 FCRD (Factorial completely randomized design)
Number of factors	2
FACTOR A	Six colors <ol style="list-style-type: none"> 1. Green 2. Red 3. Yellow 4. Pink 5. Blue 6. Black
FACTOR B	Two Concentration <ol style="list-style-type: none"> 1. 5% 2. 10%
Number of treatments	12
Number of replications	3
Number of flower stalks per bottle	2

Table 2 : Treatment Structure Based on Dye Colour and Concentration

Treatment	Treatment Details
T ₁	Green dye @ 5%
T ₂	Green dye @ 10%
T ₃	Red dye @ 5%
T ₄	Red dye @ 10%
T ₅	Yellow dye @ 5%
T ₆	Yellow dye @ 10%
T ₇	Pink dye @ 5%
T ₈	Pink dye @ 10%
T ₉	Blue dye @ 5%
T ₁₀	Blue dye @ 10%
T ₁₁	Black dye @ 5%
T ₁₂	Black dye @ 10%

The experiment used cut flowers of carnation and tuberose arranged in a 2 Factorial Completely Randomized Design (2FCRD) with two factors: tinting

colour and concentration. Six colours at 5% and 10% levels produced twelve treatments, each replicated three times. For each replication, three carnation

flowers were placed in one bottle (Table 2). Dye solutions contained 2% sucrose, 300 ppm citric acid, and were made up to 100 mL with distilled water. In

total, 36 bottles were prepared to ensure uniformity and accurate replication.

Table 3: Observational Variables with Corresponding Formulas and Standard Units

SL. No.	observation	equations	SI unit
1	Weight of Spike (g)	$\frac{W_t - W_0}{W_0} \times 100$	Gram(g)
2	Flower Diameter (mm)	$D = \frac{D_1 + D_2}{2}$	millimetre (mm)
3	Deterioration (%)	$\frac{\sum S_t}{n \times S_{max}} \times 100$	percent (%)
4	Dye Uptake (mL)	$U = V_0 - V_t$	millilitre (mL)
5	Flower Retention (%)	$Retention \% = \frac{N_t}{N_0} \times 100$	percent (%)

Observations were recorded to evaluate the physiological and aesthetic responses of carnation N to tinting treatments. Parameters measured included spike weight (g), expressed as percentage change to assess hydration; flower diameter (mm), calculated from two perpendicular measurements; deterioration (%), derived from visual scoring; and dye uptake (mL), measured as the volume absorbed. Additional assessments included time of tinting (h), colour intensity (score), flower retention (%), and sensory evaluations of shape, appearance, and overall acceptability using standardised rating scales (Table 3). Together, these measurements provided a clear and quantifiable basis for comparing treatment effects on flower quality and postharvest performance.

The effects of colour and concentration treatments were evaluated in this study utilizing a two-factor Completely Randomized Design (CRD), with statistical analysis carried out using Kerala Agricultural University's Resin and Grapes software. The results' dependability was confirmed by the analysis, which showed significant treatment effects ($p < 0.05$). The means were separated and specific differences between treatment combinations were found using Duncan's Multiple Range Test (DMRT). The validity and robustness of the study's conclusions were strengthened by the rigorous and organized evaluation of treatment effects made possible by the factorial design, which assesses responses based on combinations of factor levels and their interactions.

Result and Discussion

Effect of colour and concentration on cut flower weight

The weight of carnation explants was significantly influenced by both color and concentration, with green consistently yielding the highest weights and 10% concentration outperforming 5% at all observation times. The green \times 10% combination produced the most biomass, but red \times 10% and pink \times 10% produced the least, according to a strong interaction between the two elements. These patterns imply that, particularly when combined with greater concentration levels, favourable spectral circumstances improve metabolic activity, photosynthesis, and resource use efficiency. Overall, the findings show that optimum explant weight growth in controlled culture systems requires controlling both color environment and concentration.

The significant effects of tint colour and concentration on explant weight observed in this study align with previous findings that light spectrum and solute levels strongly influence plant growth (Hogewoning *et al.*, 2010; Taiz *et al.*, 2015). The superior performance of the green \times 10% treatment suggests enhanced photosynthetic efficiency and metabolic activity under favourable spectral conditions, as also reported by Bula *et al.* (1991) and Johkan *et al.* (2010). In contrast, the lower weights under darker colours and higher concentrations may reflect reduced light penetration or osmotic stress (Table 4). Overall, these results support earlier conclusions that environmental and chemical factors interact synergistically to regulate biomass accumulation (Heo *et al.*, 2002; Massa *et al.*, 2008)

Variation in floral diameter under different tinting treatments

Floral diameter was significantly influenced by both tint colour and dye concentration. Green-treated flowers consistently showed the largest diameters (Fig 2), followed by blue, while red and yellow produced smaller blooms. Higher concentration (10%) enhanced petal expansion compared to 5%, likely due to improved pigment absorption and water uptake (Nayak *et al.*, 2025). The combination of green tint and 10% concentration resulted in the greatest floral diameter, indicating a synergistic effect between colour and concentration. These findings agree with previous studies (Ebrahimzadeh, 2015; Rani & Singh, 2019; Gupta & Soni, 2020) and highlight that optimizing tint type and concentration can enhance petal expansion and overall floral quality. The study showed that both tint colour and dye concentration significantly influenced floral diameter, with green treatments producing the largest blooms. National Horticulture Board 2022 Recent research supports that highly soluble pigments enhance vascular flow and hydration, promoting greater petal expansion (Sharma & Kaur, 2021; Pangtu *et al.*, 2025). The stronger response at 10% concentration aligns with findings that higher solute levels improve osmotic uptake within safe limits (Gupta & Soni, 2020; Dhiman *et al.*, 2023). Overall, the green \times 10% combination demonstrates a synergistic effect, Ardakani *et al.* (2022) reinforcing the importance of optimizing both pigment type and concentration for improved floral development.

Effect of tint colour and concentration on postharvest deterioration

Floral deterioration varied significantly across tint colours and dye concentrations, increasing steadily over time (Gobade *et al.*, 2024) (Table 5). Darker tints such as black, red, pink, and yellow showed the highest deterioration levels (Fig. 3), (Panwar *et al.*, 2024) suggesting that these pigments may disrupt water balance or accelerate oxidative stress. In contrast, blue and green treatments exhibited lower deterioration, Yong *et al.*, (2014) indicating slower senescence and better freshness retention. Higher concentration (10%) further reduced deterioration compared to 5%, likely due to improved pigment stability and osmotic regulation, consistent with Gupta and Soni (2020). A strong interaction effect showed that combinations like blue \times 10% and green \times 10% minimized deterioration, while red \times 10% and pink \times 5% accelerated it. These patterns align with recent findings that dye solubility and colour intensity influence water balance, membrane stability, and overall vase life (Sharma & Kaur, 2021; Dhiman *et al.*, 2023; Pangtu *et al.*, 2025).

Overall, the results highlight that cooler tint colours and higher concentrations promote greater physiological stability and reduce senescence in cut carnations.

Variation in dye absorption across tint colours and concentrations

The study showed that dye uptake in carnation flowers was significantly affected by tint color, concentration, and their interaction, with absorption steadily increasing from Day 2 to Day 8 as dye moved through the xylem (Table 6). Green dye consistently resulted in the highest uptake, followed by blue, likely due to greater solubility and mobility within vascular tissues, while red, yellow, pink, and black dyes showed reduced absorption, supporting earlier findings on pigment density and vascular flow limitations (Sharma & Kaur, 2021; Pangtu *et al.*, 2025). Flowers treated with 10% dye solution absorbed more than those treated with 5%, reflecting enhanced osmotic pull and capillary movement, consistent with Gupta and Soni (2020). The green \times 10% combination produced the maximum dye uptake, indicating a synergistic effect between tint properties and concentration, similar to interaction patterns reported by Dhiman *et al.* (2023). Joyce *et al.*, (2012) confirm that cooler tint colors and higher concentrations improve dye absorption efficiency, color uniformity, and postharvest performance in carnations.

Effect of colour and concentration on tinting duration

The study revealed that tinting time in carnations was strongly influenced by tint color, dye concentration, and their interaction. Green dye produced the fastest tinting, while darker colors such as black, red, pink, and yellow required longer periods, with blue showing an intermediate rate. A higher concentration (10%) consistently reduced tinting time compared to 5%, indicating that stronger pigment intensity enhances diffusion (Table 7). Faster tinting in combinations like green \times 10% and blue \times 10% suggests that pigment solubility and molecular properties drive absorption efficiency. These results align with recent findings that dye characteristics and concentration significantly affect floral color uptake (Kaur & Bhatti, 2017; Purbajanti *et al.*, 2021). The low coefficient of variation confirms high reliability, and overall, the findings highlight that lighter pigments and higher concentrations optimize tinting efficiency in carnations.

Effect of tinting treatments on sensory attributes of carnation flowers

The study showed that tint color and concentration significantly influenced the sensory qualities of carnation flowers, including appearance, flower retention, and overall acceptability (Shravya, 2017). Green dye consistently produced the highest sensory scores (Fig. 4), particularly at the 10% concentration, indicating a strong positive effect of both pigment type and intensity on visual appeal. Blue and pink followed in performance, while black and red received lower ratings. These results align with recent studies showing that higher dye concentrations enhance colour vibrancy and uniformity (Sneha *et al.*, 2019) but may also introduce mild physiological stress similar to that observed in roses and chrysanthemums (Singh & Sharma, 2020). The significant interaction between colour and concentration suggests that pigment chemistry and uptake efficiency govern sensory responses supporting reports that differences in anthocyanin composition influence hue stability and brightness (Morimoto *et al.*, 2021 & Panwar *et al.*, 2022). Overall, the findings highlight that optimal sensory quality is achieved with moderate-to-high concentrations, particularly green at 10%, providing strong practical value for commercial tinting applications (Table 8).

Conclusion

This study clearly shows that tinting colour and dye concentration have a substantial impact on the physiological behaviour, structural stability, and aesthetic quality of *Dianthus caryophyllus* flowers

during vase life. Both main factors and their interaction produced significant effects across all measured parameters, including flower weight, dye uptake, deterioration rate, tinting duration, and sensory acceptability. This confirms that tinting is a process that directly affects postharvest physiology rather than being purely cosmetic. Green dye regularly outperformed the other six dyes, particularly at the 10% concentration. The flowers with the highest fresh weight, most dye uptake, least degradation, and quickest tinting time were those treated with green 10%. This better performance implies that green dye has favourable vascular mobility and solubility, which facilitates effective xylem transport, better hydration, and increased metabolic stability. Blue dye was the next best alternative, and it also worked wonderfully. Black, red, pink, and yellow, on the other hand, showed lesser absorption, more degradation, slower tinting, and lower sensory scores. These results suggest that vascular conductance is influenced by pigment density and chemical composition, which may also cause stress reactions that hasten senescence. Dye concentration was critical, with 10% outperforming 5% on most measures. Increased concentration probably improves pigment availability and osmotic pull, which improves color consistency and overall floral quality. Overall, the findings show that green dye at a 10% concentration is the most successful tinting treatment, providing excellent visual appeal, improved physiological performance, and extended vase life. These discoveries encourage more effective and scientifically based tinting techniques, which are useful for commercial floriculture.

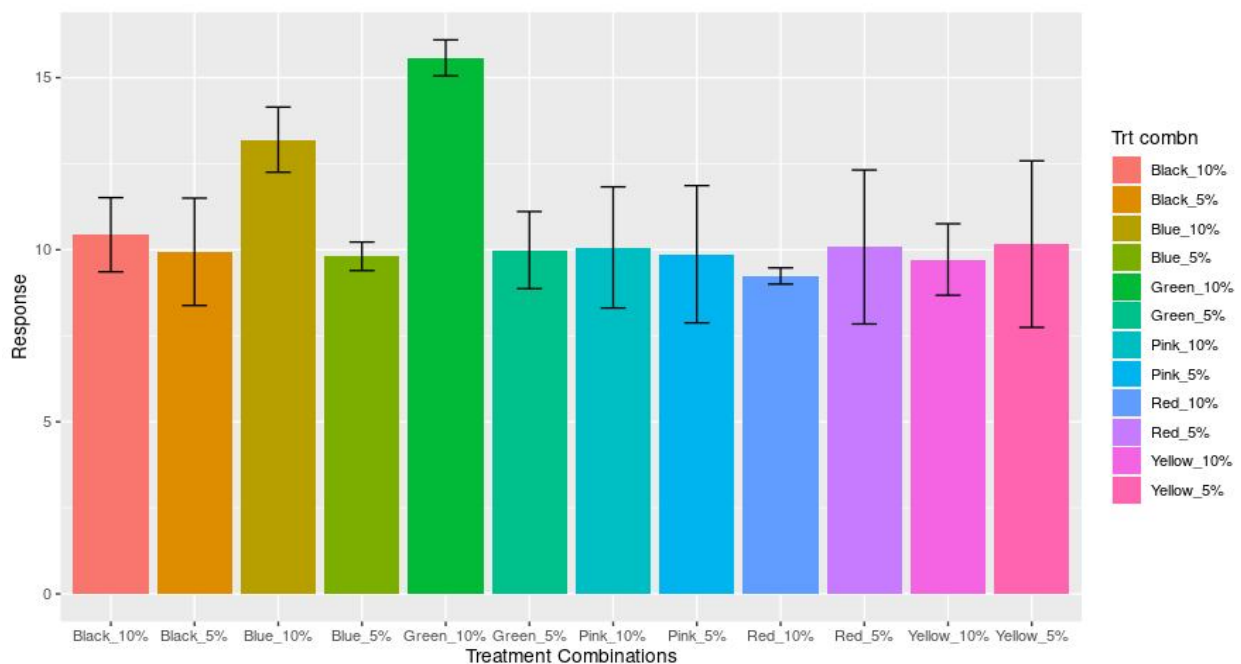


Fig. 1 : Variation in Weight Response Among Color and Concentration Treatment Combinations

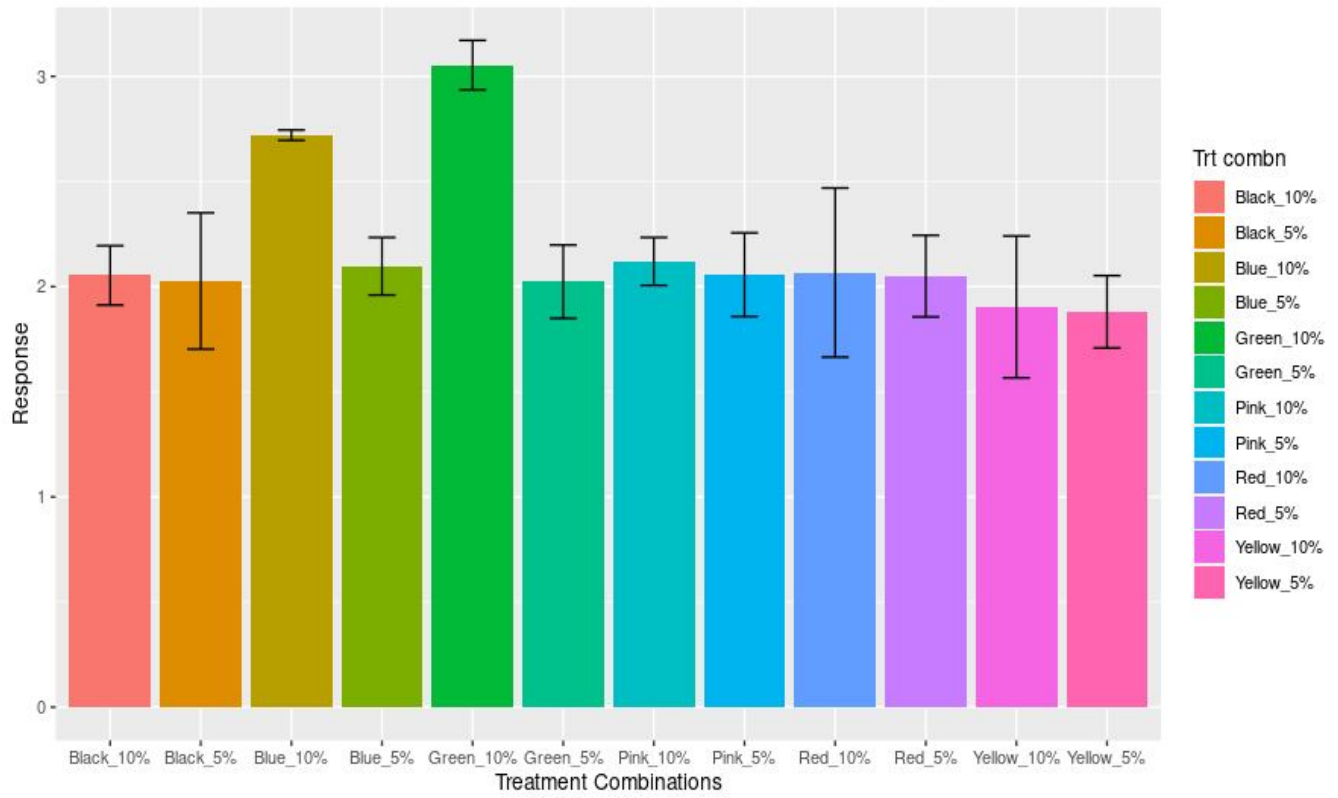


Fig. 2: Variation in floral diameter under different tinting treatments



Fig. 3 : Experimental setup showing the dye solution and the spiked carnation used for dye-uptake assessment.

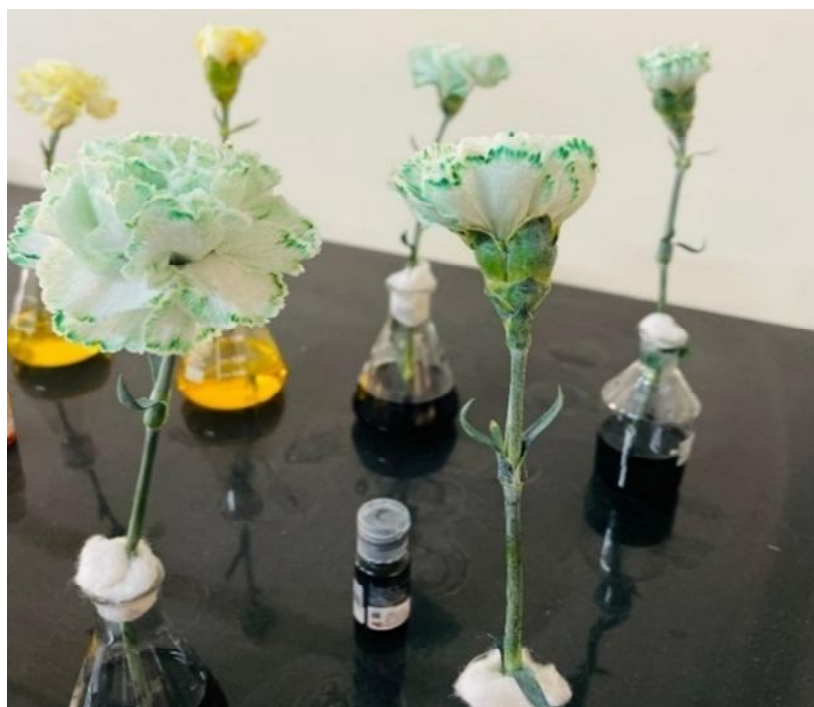


Fig. 4 : Comparative dye uptake across treatments, demonstrating that the 10% green dye concentration yielded the maximum uptake.

Table 4: Quantitative Assessment of Flower Weight (g)

FACTOR-A	Weight Day2	Weight Day4	Weight Day6	Weight Day8
Black	10.02 ± 0.37 ^c	10.16 ± 0.73 ^c	9.64 ± 0.65 ^c	10.19 ± 0.55 ^c
Blue	11.76 ± 2.00 ^b	11.16 ± 1.50 ^b	11.45 ± 1.59 ^b	11.51 ± 1.88 ^b
Green	12.60 ± 3.27 ^a	12.52 ± 2.66 ^a	12.38 ± 2.68 ^a	12.78 ± 3.08 ^a
Pink	10.03 ± 0.68 ^c	10.05 ± 0.77 ^c	9.63 ± 0.65 ^c	9.97 ± 0.69 ^c
Red	9.80 ± 0.53 ^c	9.91 ± 0.82 ^c	10.15 ± 0.69 ^c	9.66 ± 0.74 ^c
Yellow	10.05 ± 0.56 ^c	10.16 ± 0.76 ^c	9.88 ± 0.52 ^c	9.94 ± 0.71 ^c
CD (A)	0.65	0.91	0.66	0.7
SE(m)	0.22	0.31	0.23	0.24
SE(d)	0.31	0.44	0.32	0.34
FACTOR B	Weight Day2	Weight Day4	Weight Day6	Weight Day8
5%	9.91 ± 0.47 ^b	10.15 ± 0.64 ^b	9.95 ± 0.65 ^b	9.98 ± 0.61 ^b
10%	11.51 ± 2.35 ^a	11.17 ± 2.07 ^a	11.09 ± 2.12 ^a	11.37 ± 2.36 ^a
CD (B)	0.37	0.53	0.38	0.4
SE(m)	0.13	0.18	0.13	0.14
SE(d)	0.18	0.26	0.18	0.19
FACTOR A X B	Weight Day2	Weight Day4	Weight Day6	Weight Day8
Black 5%	10.12 ± 0.45 ^c	10.05 ± 0.88 ^c	9.34 ± 0.34 ^d	9.94 ± 0.63 ^{cd}
Black 10%	9.93 ± 0.33 ^c	10.27 ± 0.72 ^c	9.94 ± 0.82 ^{cd}	10.44 ± 0.43 ^c
Blue 5%	9.97 ± 0.47 ^c	9.89 ± 0.76 ^c	10.04 ± 0.33 ^{cd}	9.81 ± 0.17 ^{cd}
Blue 10%	13.56 ± 0.39 ^b	12.44 ± 0.47 ^b	12.86 ± 0.54 ^b	13.20 ± 0.38 ^b
Green 5%	9.64 ± 0.41 ^c	10.15 ± 0.24 ^c	10.02 ± 0.85 ^{cd}	9.99 ± 0.45 ^{cd}
Green 10%	15.56 ± 0.50 ^a	14.88 ± 0.94 ^a	14.73 ± 0.74 ^a	15.58 ± 0.21 ^a
Pink 5%	10.13 ± 0.63 ^c	10.21 ± 0.93 ^c	9.97 ± 0.79 ^{cd}	9.87 ± 0.80 ^{cd}
Pink 10%	9.94 ± 0.86 ^c	9.89 ± 0.73 ^c	9.29 ± 0.31 ^d	10.07 ± 0.71 ^{cd}
Red 5%	9.55 ± 0.46 ^c	10.04 ± 0.85 ^c	10.75 ± 0.17 ^c	10.08 ± 0.90 ^{cd}
Red 10%	10.04 ± 0.58 ^c	9.77 ± 0.96 ^c	9.54 ± 0.27 ^d	9.24 ± 0.10 ^d
Yellow 5%	10.05 ± 0.45 ^c	10.55 ± 0.29 ^c	9.57 ± 0.42 ^d	10.16 ± 0.97 ^{cd}
Yellow 10%	10.05 ± 0.76 ^c	9.78 ± 0.96 ^c	10.19 ± 0.45 ^{cd}	9.72 ± 0.42 ^{cd}
CD (AxB)	0.92	1.29	0.93	0.98
SE(m)	0.31	0.44	0.32	0.34
SE(d)	0.44	0.63	0.45	0.48

Table 5: Deterioration Pattern of Carnation Flowers in Response to Different Dye Treatments and Concentrations

FACTOR A	Deterioration Day 4	Deterioration Day 6	Deterioration Day 8
Black	19.68 ± 1.01 ^a	20.10 ± 0.97 ^a	20.23 ± 1.07 ^a
Blue	17.76 ± 1.75 ^b	17.65 ± 2.23 ^b	18.84 ± 1.94 ^{bc}
Green	18.08 ± 2.67 ^b	17.01 ± 3.09 ^b	18.29 ± 2.73 ^c
Pink	20.21 ± 1.08 ^a	19.83 ± 0.91 ^a	20.34 ± 1.03 ^a
Red	20.46 ± 1.47 ^a	20.59 ± 1.13 ^a	20.09 ± 1.06 ^{ab}
Yellow	20.41 ± 0.98 ^a	19.88 ± 1.24 ^a	19.78 ± 1.44 ^{ab}
CD (A)	1.34	1.32	1.33
SE(m)	0.46	0.45	0.45
SE(d)	0.65	0.64	0.64
FACTOR B	Deterioration Day4	Deterioration Day6	Deterioration Day8
5%	19.76 ± 1.12	19.73 ± 1.09 ^a	20.38 ± 0.98 ^a
10%	19.11 ± 2.38	18.63 ± 2.76 ^b	18.81 ± 1.96 ^b
CD (B)	-	0.76	0.77
SE(m)	0.26	0.26	0.26
SE(d)	0.37	0.37	0.37
AXB	Deterioration Day4	Deterioration Day6	Deterioration Day8
Black 5%	19.87 ± 0.79 ^{ab}	19.89 ± 1.24 ^a	19.92 ± 1.22 ^a
Black 10%	19.50 ± 1.36 ^{ab}	20.30 ± 0.83 ^a	20.54 ± 1.05 ^a
Blue 5%	18.97 ± 1.46 ^b	19.45 ± 1.36 ^a	20.45 ± 1.13 ^a
Blue 10%	16.54 ± 1.04 ^c	15.84 ± 0.93 ^b	17.22 ± 0.55 ^{bc}
Green 5%	20.31 ± 1.51 ^{ab}	19.71 ± 1.14 ^a	20.64 ± 1.41 ^a
Green 10%	15.84 ± 0.72 ^c	14.32 ± 0.93 ^b	15.95 ± 0.27 ^c
Pink 5%	20.16 ± 0.70 ^{ab}	19.36 ± 0.86 ^a	20.63 ± 1.09 ^a
Pink 10%	20.26 ± 1.56 ^{ab}	20.29 ± 0.84 ^a	20.06 ± 1.10 ^a
Red 5%	19.58 ± 1.75 ^{ab}	20.09 ± 1.35 ^a	20.11 ± 0.66 ^a
Red 10%	21.34 ± 0.09 ^a	21.10 ± 0.78 ^a	20.07 ± 1.53 ^a
Yellow 5%	19.65 ± 0.59 ^{ab}	19.86 ± 1.50 ^a	20.54 ± 1.07 ^a
Yellow 10%	21.17 ± 0.54 ^a	19.91 ± 1.26 ^a	19.01 ± 1.51 ^{ab}
CD (AxB)	1.89	1.87	1.88
SE(m)	0.65	0.64	0.64
SE(d)	0.92	0.91	0.91

Table 6: Dye Absorption Measured as Volume Change (mL)

FACTOR A	Dye Uptake Day2	Dye Uptake Day4	Dye Uptake Day6	Dye Uptake Day8
Black	2.02 ± 0.14 ^b	2.00 ± 0.14 ^c	1.97 ± 0.09 ^c	2.04 ± 0.09 ^c
Blue	2.31 ± 0.28 ^a	2.32 ± 0.30 ^b	2.33 ± 0.35 ^b	2.41 ± 0.34 ^b
Green	2.39 ± 0.51 ^a	2.59 ± 0.62 ^a	2.54 ± 0.44 ^a	2.54 ± 0.57 ^a
Pink	1.97 ± 0.09 ^b	1.99 ± 0.14 ^c	1.99 ± 0.17 ^c	2.09 ± 0.07 ^c
Red	1.99 ± 0.15 ^b	1.95 ± 0.13 ^c	1.96 ± 0.10 ^c	2.06 ± 0.11 ^c
Yellow	2.01 ± 0.10 ^b	1.98 ± 0.09 ^c	2.00 ± 0.17 ^c	1.89 ± 0.10 ^d
CD (A)	0.14	0.16	0.17	0.11
SE(m)	0.05	0.05	0.06	0.04
SE(d)	0.07	0.08	0.08	0.05
FACTOR B	Dye Uptake Day2	Dye Uptake Day4	Dye Uptake Day6	Dye Uptake Day8
5%	1.97 ± 0.12 ^b	1.99 ± 0.12 ^b	2.04 ± 0.12 ^b	2.02 ± 0.10 ^b
10%	2.26 ± 0.34 ^a	2.28 ± 0.47 ^a	2.23 ± 0.43 ^a	2.32 ± 0.44 ^a
CD (B)	0.08	0.09	0.1	0.06
SE(m)	0.03	0.03	0.03	0.02
SE(d)	0.04	0.04	0.05	0.03
AXB	Dye Uptake Day2	Dye Uptake Day4	Dye Uptake Day6	Dye Uptake Day8
Black 5%	1.99 ± 0.17 ^c	2.01 ± 0.16 ^c	2.03 ± 0.11 ^c	2.03 ± 0.13 ^{cd}
Black 10%	2.05 ± 0.13 ^c	2.00 ± 0.15 ^c	1.92 ± 0.03 ^c	2.05 ± 0.06 ^c
Blue 5%	2.06 ± 0.07 ^c	2.06 ± 0.03 ^c	2.04 ± 0.14 ^c	2.10 ± 0.06 ^c

Blue 10%	2.56 ± 0.09 ^b	2.57 ± 0.18 ^b	2.62 ± 0.17 ^b	2.72 ± 0.01 ^b
Green 5%	1.93 ± 0.17 ^c	2.03 ± 0.16 ^c	2.15 ± 0.06 ^c	2.02 ± 0.07 ^{cde}
Green 10%	2.84 ± 0.04 ^a	3.15 ± 0.02 ^a	2.94 ± 0.12 ^a	3.05 ± 0.05 ^a
Pink 5%	1.90 ± 0.08 ^c	1.99 ± 0.18 ^c	2.00 ± 0.17 ^c	2.06 ± 0.08 ^c
Pink 10%	2.04 ± 0.04 ^c	1.99 ± 0.12 ^c	1.97 ± 0.20 ^c	2.12 ± 0.05 ^c
Red 5%	1.97 ± 0.15 ^c	1.88 ± 0.07 ^c	1.99 ± 0.07 ^c	2.05 ± 0.08 ^{cd}
Red 10%	2.02 ± 0.18 ^c	2.02 ± 0.16 ^c	1.92 ± 0.13 ^c	2.07 ± 0.16 ^c
Yellow 5%	1.96 ± 0.07 ^c	1.99 ± 0.07 ^c	1.99 ± 0.19 ^c	1.88 ± 0.07 ^e
Yellow 10%	2.06 ± 0.11 ^c	1.97 ± 0.13 ^c	2.01 ± 0.20 ^c	1.90 ± 0.14 ^{de}
CD (AxB)	0.2	0.22	0.24	0.15
SE(m)	0.07	0.08	0.08	0.05
SE(d)	0.1	0.11	0.12	0.07

Table 7: Time Required for Complete Tinting of Carnation Flowers under Various Dye Treatments

FACTOR A	Time Tinting (hour)
Black	5.05 ± 0.11 ^a
Blue	4.76 ± 0.41 ^b
Green	4.50 ± 0.60 ^c
Pink	4.92 ± 0.09 ^a
Red	5.04 ± 0.15 ^a
Yellow	5.00 ± 0.13 ^a
CD (A)	0.14
SE(m)	0.05
SE(d)	0.07
FACTOR B	Time Tinting (hour)
5%	5.04 ± 0.13 ^a
10%	4.72 ± 0.43 ^b
CD (B)	0.08
SE(m)	0.03
SE(d)	0.04
AXB	Time Tinting hour
Blackx5%	5.09 ± 0.09 ^a
Blackx10%	5.01 ± 0.13 ^{ab}
Bluex5%	5.12 ± 0.04 ^a
Bluex10%	4.39 ± 0.18 ^c
Greenx5%	5.04 ± 0.08 ^{ab}
Greenx10%	3.96 ± 0.14 ^d
Pinkx5%	4.87 ± 0.03 ^b
Pinkx10%	4.96 ± 0.12 ^{ab}
Redx5%	5.11 ± 0.13 ^a
Redx10%	4.97 ± 0.14 ^{ab}
Yellowx5%	4.98 ± 0.19 ^{ab}
Yellowx10%	5.03 ± 0.05 ^{ab}
CD (AxB)	0.2
SE(m)	0.07
SE(d)	0.1

Table 8: Sensory Evaluation of Tinted Carnation Flowers under Different Dye Colors and Concentrations

FACTOR A	Color	Flower Retention	Shape & Appearance	Overall Acceptability
Black	5.67 ± 1.03 ^c	6.83 ± 0.41 ^{abc}	6.00 ± 1.10 ^b	5.83 ± 0.75 ^b
Blue	6.67 ± 1.51 ^b	7.00 ± 1.26 ^{ab}	6.83 ± 1.47 ^b	6.50 ± 1.64 ^b
Green	7.67 ± 1.63 ^a	7.33 ± 1.97 ^a	8.00 ± 1.10 ^a	7.83 ± 1.33 ^a
Pink	6.17 ± 0.41 ^{bc}	5.67 ± 0.82 ^d	6.33 ± 0.52 ^b	5.83 ± 0.41 ^b
Red	5.67 ± 0.82 ^c	6.00 ± 0.89 ^{cd}	6.00 ± 0.63 ^b	6.17 ± 0.75 ^b
Yellow	6.00 ± 0.89 ^{bc}	6.17 ± 0.98 ^{bcd}	6.17 ± 0.75 ^b	6.00 ± 1.10 ^b
CD (A)	0.87	0.87	0.91	0.79
SE(m)	0.30	0.30	0.31	0.27

SE(d)	0.42	0.42	0.44	0.38
FACTOR B	Color	Flower Retention	Shape & Appearance	Overall Acceptability
5%	5.83 ± 0.86 ^b	6.17 ± 0.92 ^b	6.11 ± 0.83 ^b	5.78 ± 0.81 ^b
10%	6.78 ± 1.44 ^a	6.83 ± 1.42 ^a	7.00 ± 1.28 ^a	6.94 ± 1.30 ^a
CD (B)	0.5	0.5	0.53	0.46
SE(m)	0.17	0.17	0.18	0.16
SE(d)	0.24	0.24	0.25	0.22
AXB	Color	Flower Retention	Shape & Appearance	Overall Acceptability
Black 5%	6.33 ± 1.15 ^b	7.00 ± 0.00 ^{bc}	5.67 ± 1.15 ^d	5.67 ± 1.15 ^{bc}
Black 10%	5.00 ± 0.00 ^c	6.67 ± 0.58 ^{cd}	6.33 ± 1.15 ^{cd}	6.00 ± 0.00 ^{bc}
Blue 5%	5.33 ± 0.58 ^{bc}	6.00 ± 1.00 ^{cde}	5.67 ± 1.15 ^d	5.00 ± 0.00 ^c
Blue 10%	8.00 ± 0.00 ^a	8.00 ± 0.00 ^{ab}	8.00 ± 0.00 ^{ab}	8.00 ± 0.00 ^a
Green 5%	6.33 ± 1.15 ^b	5.67 ± 1.15 ^{de}	7.00 ± 0.00 ^{bc}	6.67 ± 0.58 ^b
Green 10%	9.00 ± 0.00 ^a	9.00 ± 0.00 ^a	9.00 ± 0.00 ^a	9.00 ± 0.00 ^a
Pink 5%	6.00 ± 0.00 ^{bc}	5.33 ± 0.58 ^e	6.33 ± 0.58 ^{cd}	6.00 ± 0.00 ^{bc}
Pink 10%	6.33 ± 0.58 ^b	6.00 ± 1.00 ^{cde}	6.33 ± 0.58 ^{cd}	5.67 ± 0.58 ^{bc}
Red 5%	5.33 ± 0.58 ^{bc}	6.00 ± 1.00 ^{cde}	6.00 ± 0.00 ^{cd}	5.67 ± 0.58 ^{bc}
Red 10%	6.00 ± 1.00 ^{bc}	6.00 ± 1.00 ^{cde}	6.00 ± 1.00 ^{cd}	6.67 ± 0.58 ^b
Yellow 5%	5.67 ± 1.15 ^{bc}	7.00 ± 0.00 ^{bc}	6.00 ± 1.00 ^{cd}	5.67 ± 1.15 ^{bc}
Yellow 10%	6.33 ± 0.58 ^b	5.33 ± 0.58 ^e	6.33 ± 0.58 ^{cd}	6.33 ± 1.15 ^b
CD (AxB)	1.22	1.22	1.29	1.12
SE(m)	0.42	0.42	0.44	0.38
SE(d)	0.59	0.59	0.62	0.54

References

- Aalifar, M., Aliniaiefard, S., Arab, M., Zare Mehrjerdi, M., Dianati Daylami, S., Serek, M., ... & Li, T. (2020). Blue light improves vase life of carnation cut flowers through its effect on the antioxidant defense system. *Frontiers in Plant Science*, *11*, 511.
- Calcareum, S., feather, G., & Amcena, A. (2024). the flower garden. *nineteenth-century gardens and gardening: volume vi: the art of the gardener*, 51.
- Dehestani-Ardakani, M., Gholamnezhad, J., Alizade, S., Meftahizadeh, H., & Ghorbanpour, M. (2022). Salicylic acid and herbal extracts prolong vase life and improve quality of carnation (*Dianthus caryophyllus* L.) flowers. *South African Journal of Botany*, *150*, 1192–1204
- Faust, J. E., & Dole, J. M. (2021). Major cut flowers. *Cut flowers and foliage*, 48-149.
- Gebremedhin, S. (2020). Global trends and competitiveness in the international cut-flower trade. *Journal of Agricultural Economics and Development*, *9(3)*, 45–54.
- Gobade, N. (2024). Production technology of carnation. *Production technology of fruits and flowers*, 94-110.
- Hang, Y., Li, H., & Wang, J. (2021). Effects of highlighter and food dye tinting on physiological traits and vase life of cut roses Implications for carnation tinting systems. *Postharvest Biology and Technology*, *180*, 111604.
- Hill, J., B. W. W. Grout, and R. D. (2008). Taylor. "Assessment of petal colour change in cut-flower carnation'santorini'during vase life." *ix International Symposium on Postharvest Quality of Ornamental Plants*, 847.
- Hossain, M., & Islam, M. S. (2022). Growth and transformation of the floriculture industry in Asia: Opportunities and policy interventions. *Asian Journal of Agriculture and Development*, *19(1)*, 67–78.
- Jawaharlal, M. et al. (2009). "A technical guide on carnation." *Tamil Nadu Agricultural University, Coimbatore*, 1-56.
- Joyce, D., & Faragher, J. (2012). *Cut flowers. Crop postharvest: Science and technology. Perishables.* Wiley-Blackwell. Ames, EUA, 414-438.
- Mebakerlin, M. S., & Chakravorty, S. (2015). Value addition in flowers. In *Value Addition of Horticultural Crops: Recent Trends and Future Directions* (pp. 83-99). New Delhi: Springer India.
- National Horticulture Board. (2022). Indian horticulture database 2022: Floriculture statistics and national mission achievements. *Ministry of Agriculture and Farmers Welfare, Government of India*.
- Nayak, A., Pattanaik, A., Samantaray, P., Pradhan, I., Sahoo, R., & Mohanty, S. (2025). Cultivation and Cultural Practices Followed in Carnation

- (*Dianthus caryophyllus* L.) for Better Production: A Review. *Agricultural Reviews*, **46(4)**, 612-620.
- Onozaki, T. (2018). Breeding of carnations (*Dianthus caryophyllus* L.) for long vase life. *Breeding science*, **68(1)**, 3-13.
- Pace, A., Dunn, B. L., & Fontanier, C. (2023). Evaluating various colors of persistent luminescent powders on rose cut flowers Implications for carnation tinting. *Hort Science*, **58(11)**, 1400–1409.
- Pace, A., Dunn, B. L., Fontanier, C., Goad, C., & Singh, H. (2022). Cut-flower carnation photoluminescence: Potential new value-added product. *Hort Science*, **57(3)**, 491-496.
- Pangtu, S., Sharma, P., Dhiman, S. R., Dhiman, M. R., Kashyap, B., & Chhabra, R. (2025). Evaluating the effectiveness of tinting with various food dyes for enhancing the value and quality of ornamental kale genotypes. *Journal of Applied Horticulture*, **27(1)**, 82-88.
- Panwar, S., Gupta, Y. C., Kumari, P., Thakur, N., & Mehraj, U. (2022). Carnation. In *Floriculture and ornamental plants* (pp. 1-22). Singapore: Springer Singapore.
- Rani, P., & Singh, N. (2014). Senescence and postharvest studies of cut flowers: a critical review. *Pertanika Journal of Tropical Agricultural Science*, **37(2)**.
- Sarhan, A. M., Heikal, A. A., Saadawy, F. M., ElDeen, T. N., & Elkareem, K. A. (2023). Effect of some chemical and natural preservative solutions on vase life, water relations and some chemical composition of *Dianthus caryophyllus* L. cut flowers. *Advances in Horticultural Science*, **37(3)**, 255-270.
- Shravya, p. (2017). studies on the effect of different food colours and preservatives on dyeing and vase life of rose, carnation and chrysanthemum flowers.
- Singh, A., & Kumar, R. (2023). Floriculture development in India: Economic contributions, market expansion, and technological adoption. *Indian Journal of Horticulture*, **80(2)**, 215–224.
- Sneha, M., Kukanoor, L., Satish Patil, R., Shiragur, M., Mahantesh Naik, B. N., & Thippanna, K. S. (2019). Standardization of Dual Colour Tinting Technology in Gerbera and Carnation. *Int. J Curr. Microbiol. App. Sci*, **8(09)**, 2339-2348.
- Sowmeya, S., Kumaresan, S., & Priya, L. (2017). Effect of multi colours in tinting techniques in cut flowers (rose and carnation). *Chemical science review and letters*, **6(24)**, 250-253.
- Vijay, J., & Baweja, H. S. (2025). Value addition in Floriculture: A review. *Journal of Ornamental Horticulture*, **28(1)**, 9-19.
- Wang, M., Pi, Z., Pan, Z., Li, X., Zhong, L., Cheng, Y., ... & Zhang, F. (2025). Studies on the mother flower carnation: past, present and future. *Horticulture Research*, uhaf118.
- Yong, L. L., Liu, H., You, Y. L., Sun, J., Yi, C., Li, Y. B., Jiang, Y. M., & Wu, J. S. (2014). Quality deterioration of cut carnation flowers involves antioxidant systems and energy status. *Scientia Horticulture*, **170**, 45–52.
- Zeiri, A., Mulinge, W., & Birhanu, A. (2021). Export performance and market dynamics of major cut-flower producing countries. *International Journal of Agricultural Policy and Research*, **9(4)**, 102–112.