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Evaluating the effectiveness of tinting with various food dyes for enhancing the value and quality of ornamental kale genotypes

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Abstract

Tinting is a crucial technique for enhancing the visual appeal of flowers and increasing their market value. This study aimed to standardize the use and concentration of food dyes for tinting various ornamental kale genotypes. Conducted at Dr. YS Parmar UHF in Nauni, Solan, H.P., the research focused on assessing how different food dyes and their concentrations influenced coloration. In this experiment, three genotypes (Kt OK-2, Kt DH-19, and Nagoya) were tinted with food dyes at two concentrations *viz*., 3% and 5% for 24 hours. The results revealed that tinting with Apple Green dye for 24 hours achieved the maximum vase life, the shortest time to visible colour appearance, and the lowest dye solution uptake. Overall, all the dyes proved effective for tinting Ornamental Kale. Among the genotypes, 'Kt OK-2' produced the most visually appealing results. Thus, tinted stems provide a wider spectrum of colours while boosting the product's market value, offering increased financial benefits to florists through value addition.

Key words: Value addition, genotypes, ornamental, tinting, dye

Introduction

The floriculture industry has seen rapid global expansion, driven by increasing international market demands. However, the perishable nature of flowers presents challenges for standard postharvest management practices employed by many farmers. As a result, value addition offers a promising opportunity to diversify and enhance floral products. Ornamental Kale (Brassica oleracea var. 'Acephala' DC.) is a cool-season crop celebrated for its vibrant and attractive foliage. Ornamental Kale (*Brassica oleracea* var. Acephala) holds significance yet underutilized potential in the floral industry with its striking appearance vibrant central leaves in shades of white, pink, and red—and its ease of cultivation.

Tinting in floriculture is a valuable technique for enhancing the colour and appeal of flowers, offering numerous benefits for both the floral industry and consumers. Artificial colouring can make flowers available in colours that are not naturally present or are out of season, providing more options throughout the year. It enables customization of flower colours to match specific themes, events, or customer preferences. This is particularly useful for weddings, corporate events, and other occasions where colour coordination is important. Artificially coloured flowers often command higher prices due to their novelty and customization, leading to increased revenue for growers and florists. As per a report, a sharp increase in demand is seen for tinted roses (Vellekoop, 2021) in USA, Australia, Europe or Asia. According to the growers of Esmeralda Farms, they have seen the demand for tinted gypsophila increasing rapidly all over the world. The farm kept developing their tinting techniques and their rainbow gypsophila. Also, the increase in demand for tinted gypsophila (Vellekoop, 2019) was observed in China, as they are always looking for something new. Tinted flowers can open up new market segments and niches. For example, they can appeal to markets that value novelty and high-impact designs, such as luxury events or themed decorations. Tinted flowers can be used to create eye-catching displays in stores, attracting customers and boosting sales. The process of tinting flowers adds value to the product, providing additional income opportunities for growers and florists by allowing them to offer a premium product. In cases where certain colours of flowers are in short supply, artificial coloring can provide a solution by allowing the creation of the desired colours from readily available flowers. Tinting is particularly beneficial for white cut flowers, providing them with vibrant hues and greater market appeal (Safeena *et al.*, 2016). The use of certified food colours is both cost-effective and less hazardous, delivering consistent and vivid colours (Sowmeya *et al.*, 2017). There are several methods of application *viz*., stem absorption, petal dip and spraying. Stem absorption was selected as the most viable method for this crop due to the robust stem structure of the kale foliage, which is particularly well-suited for this technique.

Extensive research on the effect of tinting and tinting-induced changes in ornamental kale has not been done, but numerous studies have been completed for other cut flowers like tuberose, rose, and chrysanthemum (Gupta and Jhanji, 2021). There is limited comprehensive understanding of the specific effects of various food dyes for tinting ornamentals. Tinting in ornamental kale will help to provide a great variety of colours and these can be effectively utilized in the bouquet preparation, flower arrangement and stage decorations, *etc*., to increase its aesthetic value and appeal. Given the increasing demand for diverse floral products and the potential benefits for floriculturists, this study aims to evaluate the impact of different food dyes on the quality of ornamental kale. By exploring how various colours affect this crop, the study seeks to provide insights that could boost the value of ornamental kale and offer new opportunities for the floriculture industry.

Material and methods

The experiment was conducted at the Laboratory of the Department of Floriculture and Landscaping, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, H.P. The objective of the study was to determine the impact of food dyes and their concentrations on the tinting of ornamental kale.

Plant material: Ornamental Kale heads of different genotypes (Kt OK- 2, Kt DH- 19 and Nagoya) (Fig. 1) intended for tinting were procured from the Department of Floriculture and Landscaping farm. Based on preliminary studies on tinting these genotypes showed good response to tinting. Hence the experiment was formulated on these genotypes. Healthy, disease-free heads were harvested in the morning. Immediately after harvesting, the Ornamental Kale heads were placed in water and then transported to the laboratory for further processing.

Dyes used: The four ISO-certified edible food dyes used for the experiment were Apple Green Powder, Lemon Yellow Powder, and Raspberry Red Food Powder, all manufactured by International Flavours and Fragrances India Pvt. Ltd., Chennai. Additionally, Orange Red Food Powder from Ajanta Food Products Company, Parwanoo (Solan), HP, was also used for dyeing. Two concentrations, 3% and 5%, were selected based on a literature review. These were prepared by dissolving 3 g and 5 g of each dye in 100 mL of water, respectively. The most viable method *viz*., stem absorption was chosen for dyeing purposes in the current investigation. The flower stems were placed in the dye solution. The dye travels up through the xylem (the plant's vascular system) to the leaves, colouring them as it moves. Following immersion, the tinted stems were placed in a glass jar containing water for further observations. The tinted ornamental kale were later used for flower arrangements (Fig. 3).

Table 1. Treatment tinting with food dyes for enhancing the value and quality of ornamental kale genotypes detail

Genotypes under study	Food dyes	Concentration
Kt DH- 19 (G_1)	Apple Green (D_1)	3% (C_1)
Kt OK- 2 (G_2)	Lemon Yellow (D_2)	5% (C_2)
Nagoya (G_3)	Orange Red (D_3)	
	Raspberry Red (D_4)	

Fig. 1. Ornamental kale genotypes used for study

Percent increase in weight: Before immersion, the weight of each stem was recorded. The base of each stem was immersed in the dye solution for 24 hours, after which the weight of the tinted stems was recorded.

Percent increase in weight (%) = (WS24-WSBT)/ WSBT

WS24: Weight of cut stems after 24 h of tinting
WSBT: Weight of cut stems before tinting

Colour intensity: Colour intensity of the flower head was recorded by using RHS colour chart and was expressed by using the different colour codes.

Time taken for visible colour change (hours): The time taken for absorption of food dyes by cut stems was calculated based on the initiation of visible colour change in the flowers.

Vase life of the tinted stem (days): Vase life was determined by recording the days for which flower remain fresh and presentable by placing the tinted cut stems in distilled water.

Amount of coloured solution absorbed during tinting (mL/ stem): The amount of coloured solution absorbed was recorded after the 24 hours of immersion of cut stems in this solution.

Statistical analysis: Statistical analyses were performed with SPSS (SPSS Inc., Chicago, IL). Data was reported as means ± standard deviation (SD). Significant differences between means were determined using one-way ANOVA at $P < 0.05$, and comparisons of mean values using Tukey tests were also done.

Results and discussion

Time taken to visible colour appearance (h): Table 2 presents the impact of various food dyes and their concentrations on the time required for ornamental kale genotypes to visibly change colour. Analysis of the data from the 2021-22 and 2022-23 periods reveals that genotype 'Kt OK-2' exhibited the fastest visible colour change, taking just 1.03 hours and 1.12 hours, respectively, when immersed in a 5% apple green dye solution. Conversely, genotype 'Nagoya' required the longest time to show visible colour changes, with durations of 6.37 hours and 6.32 hours, respectively, when immersed in a 3% raspberry red dye solution. Overall, the pooled data in Table 2 indicate that 'Kt OK-2' had the shortest average time to visible colour appearance (1.08 hours) with a 5% apple green dye solution, while 'Nagoya' took the longest (6.34 hours) with a 3% raspberry red dye solution. These results suggest that higher dye concentrations facilitate quicker colour uptake, regardless of genotype, compared to lower concentrations. Prolonged immersion periods and increased dye concentrations improve dye translocation to the leaves. Supporting studies include Prasanth *et al.* (2020), who found that tuberose florets achieved darker hues with an 8% dye concentration and a two-hour immersion. Sowmeya *et al.* (2017) observed that rose and carnation flowers achieved vibrant colours at a 5% concentration, with rapid colour uptake within two hours for cut roses and one hour for cut carnations. Sneha *et al.* (2019) confirmed that a 5% concentration of blue, green, and orange dyes used on gerbera, carnation, and gladiolus resulted in enhanced colour uptake and intensity after 7.5 hours of immersion. Similar findings were reported by Kumar *et al.* (2015) in gladiolus, Patil and Patil (2008) in candytuft, Ranchana *et al.* (2017) in China aster, and Jyothi *et al.* (2022) in *Gypsophila.*

Table 2. Effect of food dyes and their concentration on time taken for colour uptake (hrs) and amount of solution consumed (mL) by ornamental kale genotypes

Genotypes	Dyes	Conc.	Time taken for colour uptake (hrs)			Amount of solution consumed (mL)		
			Year 1	Year 2	Pooled	Year 1	Year 2	Pooled
G_1	D_1	C_1	1.15±0.01^{ab}	1.10±0.01^{a}	1.12±0.03^{ab}	15.70±0.51^{a}	14.90±0.58^{a}	15.30±0.54^{a}
		C_2	1.03±0.03^{a}	1.12±0.19^{a}	1.08±0.02^{a}	16.63±0.44^{ab}	15.73±0.63^{ab}	16.18±0.54^{ab}
	D_2	C_1	1.26±0.01^{bc}	1.21±0.05^{a}	1.24±0.03^{abc}	16.60±0.41^{ab}	16.03±0.71^{ab}	16.31±0.56^{ab}
		C_2	1.20±0.09^{bc}	1.20±0.01^{a}	1.20±0.09^{ab}	17.56±0.34^{abc}	17.00±0.64^{abc}	17.28±0.49^{abc}
	D_3	C_1	1.46±0.01^{d}	1.37±0.05^{a}	1.41±0.04^{c}	16.63±0.44^{ab}	15.70±0.90^{ab}	16.16±0.66^{ab}
		C_2	1.31±0.01^{cd}	1.24±0.09^{a}	1.28±0.04^{bc}	18.70±0.47^{bcd}	17.76±0.92^{abcd}	18.23±0.68^{abcd}
	D_4	C_1	2.25±0.04^{f}	2.22±0.08^{b}	2.24±0.05^{d}	17.60±0.41^{abc}	16.70±0.85^{abc}	17.15±0.62^{abc}
		C_2	2.08±0.01^{e}	2.09±0.07^{b}	2.08±0.04^{d}	19.66±0.48^{cde}	18.73±0.94^{abcde}	19.20±0.70^{bcde}
G_2	D_1	C_1	3.12±0.03^{g}	3.11±0.06^{cde}	3.11±0.01^{ef}	20.63±0.44^{def}	19.56±0.86^{bcde}	20.10±0.65c^{def}
		C_2	3.06±0.02^{g}	3.04±0.05^{c}	3.05±0.03^{e}	21.60±0.37^{efg}	20.76±0.62^{cde}	21.18±0.49^{def}
	D_2	C_1	3.44±0.01^{h}	3.37±0.01^{de}	3.40±0.05^{g}	20.56±0.42^{def}	19.66±0.98^{bcde}	20.11±0.69^{cdef}
		C_2	3.32±0.01^{h}	3.26±0.03^{cde}	3.29±0.03^{fg}	21.66±0.56^{efg}	21.10±0.86^{cde}	21.38±0.71^{def}
	D_3	C_1	4.32±0.01^{ij}	4.28±0.08^{f}	4.30±0.03^{hi}	21.56±0.42^{efg}	20.66±0.87^{cde}	21.11±0.64^{def}
		C_2	4.17±0.01^{i}	4.15±0.05^{f}	4.16±0.01^{h}	22.66±0.40^{fg}	21.63±0.89^{de}	22.15±0.62^{ef}
	D_4	C_1	6.32±0.01^{lm}	6.29±0.04^{g}	6.30±0.02^{k}	22.70±0.51^{fg}	21.66±1.03^{de}	22.18±0.75^{ef}
		C_2	6.17±0.01^{kl}	6.15±0.02^{g}	6.16±0.01^{jk}	23.73±0.40^{g}	22.73±0.83^{e}	23.20±0.60^{f}
G_3	D_1	C_1	3.15±0.02^{g}	3.10±0.03^{cd}	3.12±0.02^{ef}	20.70±0.51^{def}	19.83±0.60^{bcde}	20.26±0.55^{cdef}
		C_2	3.13±0.01^{g}	3.14±0.02^{cde}	3.13±0.03^{ef}	22.56±0.42^{fg}	21.96±0.57^{de}	22.26±0.49^{ef}
	D_2	C_1	3.42±0.03^{h}	3.37±0.04^{e}	3.40±0.01^{g}	21.66±0.40^{efg}	21.06±0.70^{cde}	21.36±0.55^{def}
		C_2	3.36±0.02^{h}	3.32±0.03^{de}	3.34±0.02^{g}	22.56±0.42^{fg}	21.90±0.75^{de}	22.23±0.58^{ef}
	D_3	C_1	4.42±0.01^{j}	4.38±0.04^{f}	4.40±0.02^{i}	22.66±0.52^{fg}	21.66±1.03^{de}	22.16±0.76^{ef}
		C_2	4.22±0.02^{i}	4.18±0.03^{f}	4.20±0.01^{h}	23.70±0.47^{g}	22.76±0.92^{e}	23.23±0.68^{f}
	D_4	C_1	6.37±0.01^{m}	6.32±0.04^{g}	6.34±0.02^{k}	23.43±0.33^{g}	22.66±0.71^{e}	23.05±0.52^{f}
		C_2	6.12±0.03^{k}	6.09±0.02^{g}	6.10±0.01^{j}	23.66±0.43^{g}	22.63±0.94^{e}	23.18±0.65^{f}

Different letters in a column indicate statistically significant difference between genotypes, food dyes and concentration ($P \leq 0.05$, Tukey's HSD. D1, D2, D3, and D4 represent different food dyes: Apple Green Dye, Lemon Yellow Dye, Orange Red Dye, and Raspberry Red Dye, respectively. C1 and C2 denote the concentration levels of these dyes, specifically 3% and 5%. G1, G2, and G3 refer to the genotypes under study: Kt OK-2, Kt DH-19, and Nagoya, respectively.

Amount of dye solution uptake (mL/stem): Table 2 provides a detailed analysis of how different food dyes and their concentrations affect dye solution uptake (measured in mL per stem) by ornamental kale genotypes. The table includes pooled means from the study, showing variations in dye solution uptake over the 2021-22 and 2022-23 periods. Specifically, the genotype 'Kt OK-2' showed the lowest dye uptake, with 15.70 mL/stem and 14.90 mL/stem after 24 hours of immersion in a 3% apple green dye solution. In contrast, the genotype 'Kt DH-19' demonstrated the highest dye absorption, with 23.73 mL/stem and 22.73 mL/stem after immersion in a 5% raspberry red dye solution. The pooled data in Table 2 further confirm these findings, with 'Kt OK-2' exhibiting minimal absorption (15.30 mL/stem) in the 3% apple green dye solution, while 'Kt DH-19' displayed maximum absorption (23.20 mL/stem) in the 5% raspberry red dye solution. Supporting this, Kumari and Deb (2018) observed similar trends in tuberose flowers, where the highest absorption occurred with a 3% apple green dye and the lowest with a 1% tomato red dye. Prasanth *et al.* (2020) also found that lemon yellow, kesar yellow, orange red, and raspberry red dyes at an 8% concentration resulted in higher absorption compared to a 4% concentration. These results are consistent with findings from Mekala *et al.* (2012) and Dhaduk and Naik (2003) in their studies on tuberose.

Percent increase in weight (%): Table 3 provides an analysis of how different food dyes and their concentrations affect the percentage increase in weight of ornamental kale genotypes during the years 2021-22 and 2022-23, along with combined averages. The data indicate that among the three genotypes studied, 'Kt OK-2' showed the lowest percentage increase in weight, with 8.46% and 7.76% when dyed with a 5% apple green dye solution. Conversely, 'Kt DH-19' exhibited the highest percentage increase in weight, with 13.73% and 13.43% when dyed with a 3% raspberry red dye solution. The pooled data further reveal that 'Kt OK-2' had a weight increase of 8.16% with a 5% apple green dye, while 'Kt DH-19' achieved the maximum weight increase of 13.58% with a 3% raspberry red dye solution. These variations in weight increase can be attributed to the amount of dye solution absorbed over time.

Vase life (days): Table 3 presents an analysis of how food dyes and their concentrations affect the vase life (in days) of ornamental kale during the years 2021-22 and 2022-23, as well as the combined averages. The data indicate that different dyes, genotypes, and concentrations significantly influenced vase life. For instance, the genotype 'Kt OK-2' had the longest vase life, lasting 15.43 days and 14.80 days, when treated with a 3% apple green dye solution. In contrast, 'Kt DH-19' exhibited the shortest vase life, at 6.30 days and 6.46 days, when treated with a 5% raspberry red dye solution. The pooled data reveal that 'Kt OK-2' consistently showed the maximum vase life of 15.11 days with a 3% apple green dye solution. Conversely, the minimum vase life of 6.38 days was recorded for 'Kt DH-19' with a 5% raspberry red dye solution. The results suggest that lower concentrations of edible dyes, particularly 3% lemon yellow, generally resulted in the longest vase life across all genotypes, followed by apple green, orange red, and raspberry red. Higher concentrations, such as 5% raspberry red, led to the shortest vase life, followed by higher concentrations of orange red, apple green, and lemon yellow. Increased dye concentrations appear to shorten vase life due to accelerated ion leakage (Singh *et al.*,

Table 3. Effect of food dyes and their concentration on percent increase in weight (%) and vase life (days) of ornamental kale genotypes

Genotypes	Dyes	Concen-trations	Percent increase in weight (%)			Vase life (days)		
			Year 1	Year 2	Pooled	Year 1	Year 2	Pooled
G_1	D_1	C_1	8.63±0.40^{a}	7.86±0.76^{a}	8.25±0.58^{a}	15.43±0.21^{kl}	14.80±0.95^{de}	15.11±0.46^{ij}
		C_2	8.46±0.37^{a}	7.76±0.67^{ab}	8.16±0.52^{a}	13.33±0.17^{hij}	12.86±0.75^{bcde}	13.10±0.42^{ghij}
	D_2	C_1	9.63±0.44^{ab}	8.70±0.90^{ab}	9.16±0.66^{ab}	12.33±0.21^{l}	12.20±0.98^{e}	12.26±0.47^{h}
		C_2	9.76±0.49^{ab}	8.70±1.01^{ab}	9.23±0.73^{ab}	14.43±0.17^{jk}	13.76±1.04^{cde}	14.10±0.55^{hij}
	D_3	C_1	10.53±0.35^{abcd}	9.63±1.01^{abc}	10.08±0.55^{abc}	11.36±0.20^{ghi}	11.16±0.72^{bcde}	11.26±0.42^{defghi}
		C_2	10.80±0.52^{abcd}	9.80±1.00^{abc}	10.30±0.75^{abcd}	10.40±0.20^{defg}	10.06±0.63^{abcd}	10.23±0.33^{bcdefgh}
	D_4	C_1	11.66±0.48^{bcde}	10.80±0.90^{abc}	11.23±0.68^{abcd}	10.26±0.13^{defg}	9.73±0.73^{abcd}	10.00±0.40^{bcdefg}
		C_2	11.53±0.43^{bcde}	11.30±0.56^{abc}	11.41±0.49^{abcd}	9.33±0.17^{bcde}	8.83±0.83^{a}	9.08±0.48^{abcde}
G_2	D_1	C_1	9.633±0.37^{ab}	8.93±0.69^{abc}	9.28±0.53^{ab}	11.40±0.20^{ghi}	11.16±0.72^{abc}	11.28±0.36^{efghi}
		C_2	10.46±0.29^{abc}	9.53±0.74^{abc}	10.00±0.50^{abc}	9.50±0.25^{cdef}	9.06±0.63^{abcde}	9.28±0.36^{bcdef}
	D_2	C_1	10.56±0.42^{abcd}	9.76±0.81^{abc}	10.16±0.61^{abcd}	12.40±0.23^{hij}	11.93±1.09^{abc}	12.16±0.61^{fgh}
		C_2	11.66±0.52^{bcde}	10.70±1.01^{abc}	11.18±0.75^{abcd}	10.43±0.21^{defg}	10.73±0.43^{bcde}	10.58±0.30^{cdefgh}
	D_3	C_1	11.56±0.42^{bcde}	10.66±0.87^{abc}	11.11±0.64^{abcd}	10.23±0.12^{cdefg}	10.13±0.69^{abcde}	10.18±0.37^{bcdefg}
		C_2	12.66±0.52^{cde}	11.80±0.95^{abc}	12.23±0.73^{bcd}	8.40±0.20^{bc}	8.36±0.36^{abcd}	8.38±0.26^{abcd}
	D_4	C_1	13.73±0.50^{e}	13.43±0.64^{c}	13.58±0.55^{d}	8.40±0.20^{bc}	8.20±0.75^{abc}	8.30±0.47^{abc}
		C_2	12.66±0.52^{cde}	10.96±1.38^{abc}	11.81±0.94^{bcd}	6.30±0.15^{a}	6.46±0.46^{a}	6.38±0.26^{a}
G_3	D_1	C_1	9.66±0.48^{ab}	8.96±0.82^{abc}	9.31±0.64^{ab}	12.33±0.17^{hij}	12.83±1.01^{bcde}	12.58±0.53^{ghij}
		C_2	10.15±0.15^{ab}	8.95±0.05^{abc}	9.55±0.50^{ab}	11.15±0.15^{efghi}	10.50±0.50^{cde}	10.82±0.17^{cdefgh}
	D_2	C_1	10.63±0.34^{abcd}	9.63±0.78^{abc}	10.13±0.53^{abc}	12.70±0.51^{ijk}	11.93±0.52^{abcde}	12.31±0.09^{ghij}
		C_2	11.26±0.17^{bcd}	10.33±0.65^{abc}	10.80±0.40a^{bcd}	11.96±0.86^{ghij}	11.56±1.10^{bcde}	11.76±0.97^{efghi}
	D_3	C_1	11.63±0.37^{bcde}	10.60±0.86^{abc}	11.11±0.59^{abcd}	11.26±0.17^{fghi}	11.30±0.85^{bcde}	11.28±0.49^{efghi}
		C_2	12.50±0.25^{cde}	11.36±0.74^{abc}	11.93±0.43^{bcd}	10.73±0.46^{defgh}	10.56±1.10^{abcde}	10.65±0.75^{cdefgh}
	D_4	C_1	12.83±0.56^{de}	11.80±1.05^{abc}	12.31±0.79^{bcd}	9.06±0.82^{bcd}	8.80±1.33^{abc}	8.93±1.08^{abcde}
		C_2	13.67±0.31^{e}	12.97±0.69^{bc}	13.32±0.49^{cd}	7.60±0.26^{ab}	7.77±0.80^{ab}	7.68±0.53^{ab}

Different letters in a column indicate statistically significant difference between genotypes, food dyes and concentration ($P \leq 0.05$, Tukey's HSD) D1, D2, D3, and D4 represent different food dyes: Apple Green Dye, Lemon Yellow Dye, Orange Red Dye, and Raspberry Red Dye, respectively. C1 and C2 denote the concentration levels of these dyes, specifically 3% and 5%. G1, G2, and G3 refer to the genotypes under study: Kt OK-2, Kt DH-19, and Nagoya, respectively.

2005), which affects cell metabolism and restricts the movement of water and nutrients, thereby impacting cell turgidity. These findings are consistent with studies by Varu and Barad (2010) on tuberose, Awadhesh and Bhagwan (2013), Safeena *et al.* (2016) on tuberose, and Ranchana *et al.* (2017) on China aster, as well as Kumar *et al.* (2015) on gladiolus and Sneha *et al.* (2019) on gerbera, carnation, and gladiolus. These studies reported that lower dye concentrations and higher water absorption contribute to better water balance, reduced wilting, and extended vase life. Jyothi *et al.* (2022) found that lemon yellow dye, followed by apple green dye at 3% concentration, was the most effective in enhancing vase life for gypsophila flowers. Similarly, Prasanth *et al.* (2020) observed that a 4% concentration of dye resulted in a longer vase life for tuberose compared to an 8% concentration. For edible dyes, apple green consistently provided the longest vase life, while orange red resulted in the shortest.

Colour intensity: The assessment of colour intensity was conducted using the Royal Horticultural Society (RHS) colour chart, 24 hours after the tinting process (Table 4). Stems treated with different edible dyes—Lemon Yellow, Apple Green, Orange Red, and Raspberry Red—showed distinct colour shades. The variation in colour intensity was influenced by the dye concentration, immersion duration, and specific genotypes (Fig. 2). The results demonstrated a clear relationship between colour intensity and dye concentration, a finding supported by existing research. For instance, Mekala *et al.* (2012) observed similar trends in tuberose, while Patil and Patil (2008) reported consistent results in candy-tuft cut flowers. Ranchana *et al.* (2017) found comparable outcomes in China aster. As observed, higher dye concentrations resulted in more pronounced colour intensity. These observations align with previous studies on tuberose, candy-tuft cut flowers, and China aster, which similarly documented the impact of edible dyes on colour intensity.

Table 4. Effect of various food dyes and their concentrations on colour intensity (as per RHS colour charts) of ornamental kale genotypes

Genotype	Apple Green Dye		Lemon Yellow Dye		Orange Red Dye		Raspberry Red Dye	
	(3%)	(5%)	(3%)	(5%)	(3%)	(5%)	(3%)	(5%)
Kt OK-2	Yellow Green Group 144A	Green Group142A	Yellow Group 9A	Yellow Group 12B	Orange Group 28B	Orange Group 26B	Red Group 58B	Red Group 51A
Kt DH-19	Mildly tinted	Mildly tinted	Mildly tinted	Mildly tinted	Mildly tinted	Mildly tinted	Red Purple Group 59A	Red Purple Group 60A
Nagoya	Mildly tinted	Mildly tinted	Mildly tinted	Mildly tinted	Mildly tinted	Mildly tinted	Red Purple Group 70A	Red Purple Group 61A

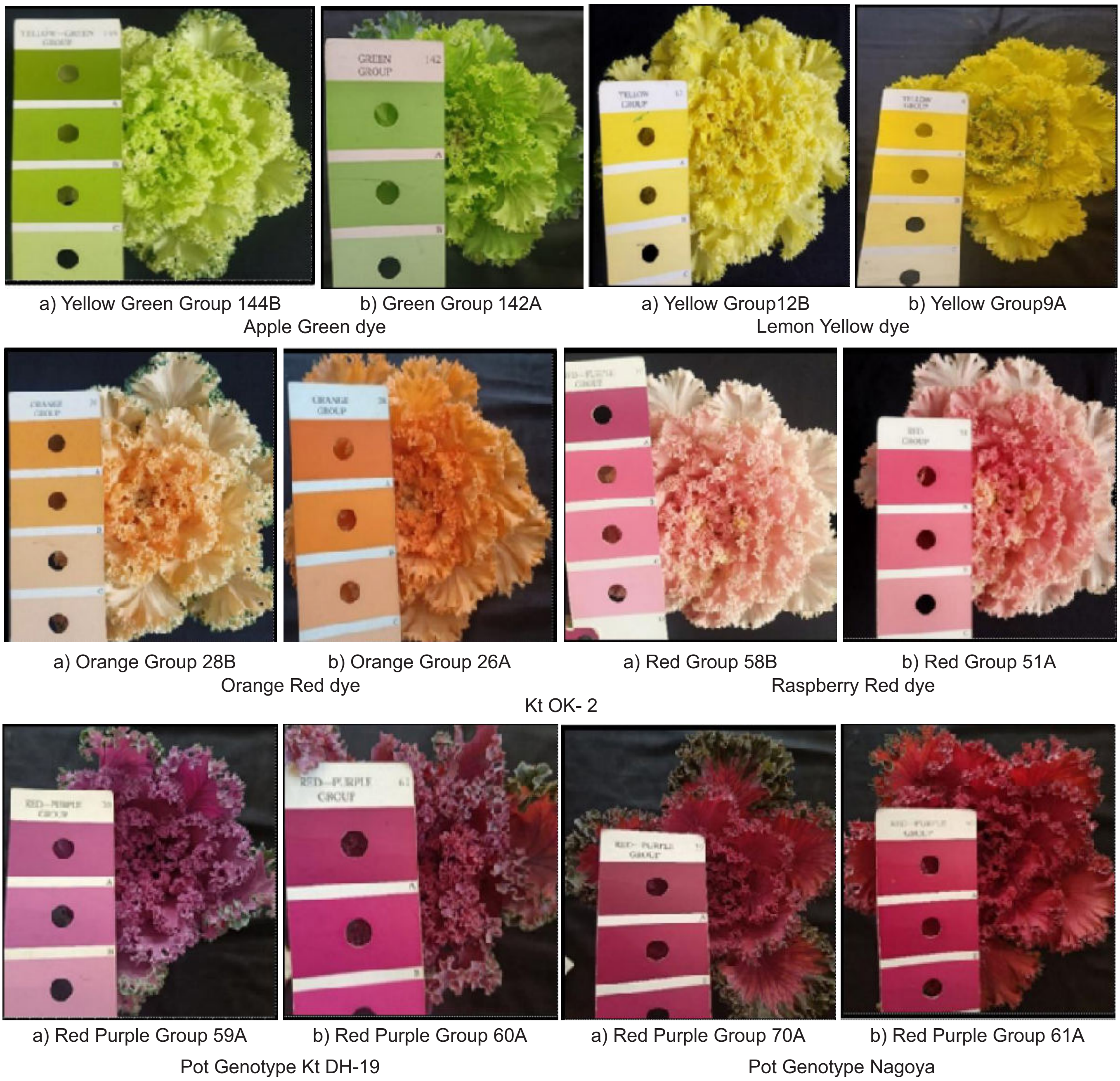

Fig. 2. Effect of different food dyes and their concentrations on tinting of ornamental kale genotypes (a- 3% and b- 5%)

Fig. 3. Utilization of tinted flowers of ornamental kale in flower arrangements

Analysis of food dye concentration on ornamental kale genotypes: The bar diagrams in Fig. 4 compares the impact of different food dye concentrations on various ornamental kale genotypes. At a 5% concentration, the genotype 'Kt OK-2' tinted with Apple Green dye exhibited the shortest time for colour visibility, the highest dye solution uptake, the smallest increase in weight percentage, and the maximum vase life compared to the other genotypes ('Kt DH-19' and 'Nagoya'). In contrast, at

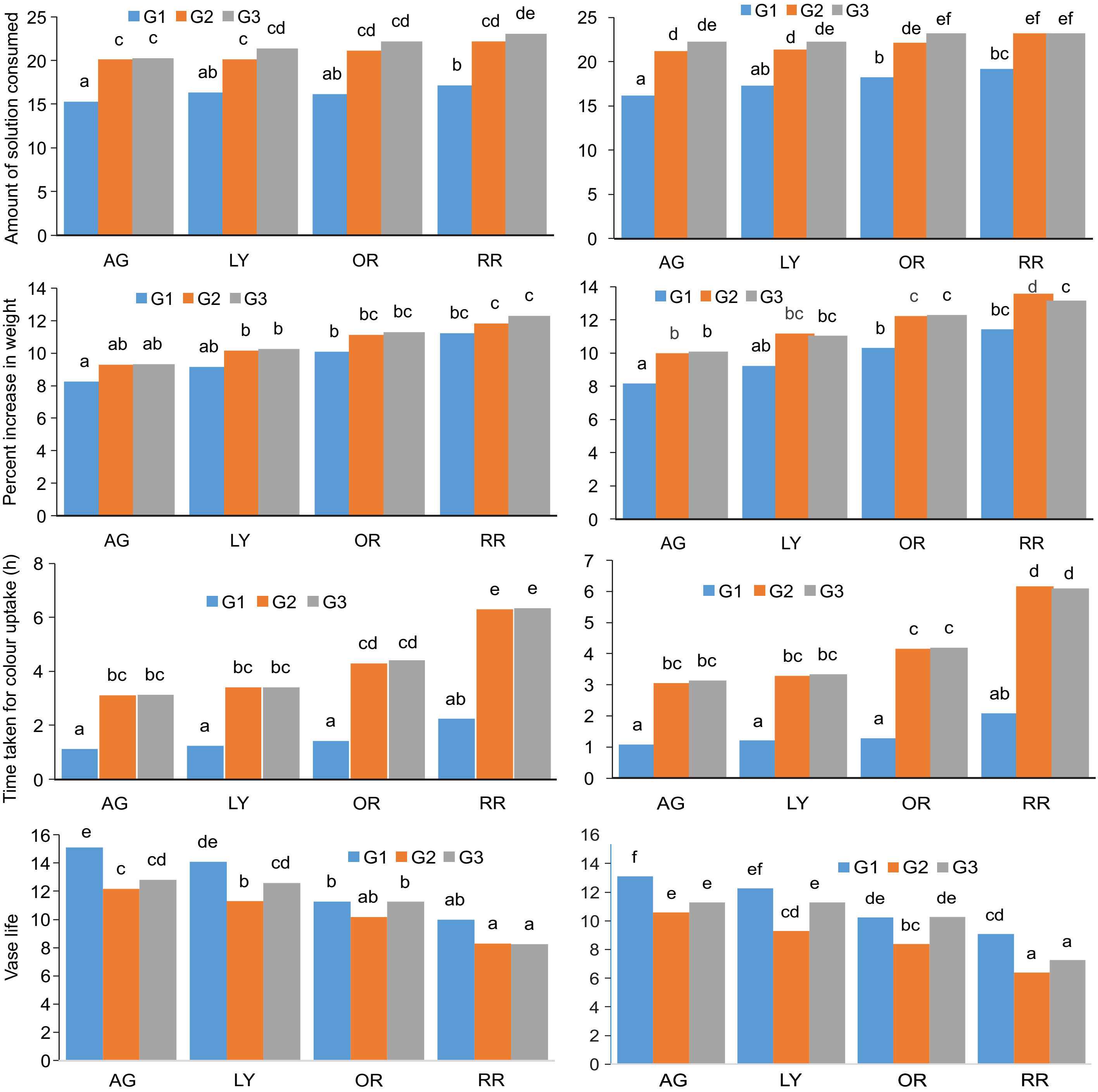

Fig. 4. Diagram representing the influence of food dyes (AG: Apple Green, LY: Lemon Yellow: OR: Orange Red: RR: Raspberry Red) and their concentration [3% (left) & 5% (right)] on different genotypes (Kt OK-2, Kt DH-57 and Nagoya)

a 3% concentration, 'Kt OK-2' showed the least dye solution uptake, the greatest increase in weight percentage, a longer time for colour to become visible and the longest vase life with Apple Green dye compared to 'Kt DH-19' and 'Nagoya'.

The success of the floral industry increasingly hinges on enhancing the fresh flower market through value addition. Value-added and post-harvest techniques are becoming vital in the flower trade. Tinting ornamental kale genotypes with Apple Green dye for 24 hours resulted in the longest vase life, the shortest time for visible colour appearance, and the lowest dye solution uptake. Generally, all dyes were effective for tinting ornamental kale genotypes. Among the genotypes, 'Kt OK-2' produced the most visually appealing results. Therefore, tinted stems not only broaden the colour range available but also offer added value, potentially increasing farmers' income through enhanced product offerings.

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