Indian Journal of Agricultural Sciences **91** (1): 154–8, January 2021/Article
https://doi.org/10.56093/ijas.v91i1.110953

Influence of tinting on physiological and keeping quality parameters of tuberose (*Polianthus tuberosa*) spikes

ARADHIKA GUPTA and SHALINI JHANJI*

Punjab Agricultural University, Ludhiana 141 001, India

Received: 19 April 2019; Accepted: 08 September 2020

ABSTRACT

Tinting adds not only variation to flower colours but also to economy of farmers. The different food colours are being used for tinting but little is known about their action. So, the present investigation to evaluate the effect of different food colours on physiological and keeping quality parameters of tuberose (*Polianthus tuberosa* L.) spikes was conducted at Punjab Agricultural University during 2017–18. The tuberose spikes cv. Prajwal were tinted with food dyes, viz. Apple green, Classic blue, Orange red and Rose pink @ 1% alone and supplemented with sucrose (2%) and citric acid (300 ppm) for 1 and 2 hrs. Tinting had no adverse effect on vase life although other quality parameters, viz. change in weight, dye solution uptake, opening of floret, number of florets drop/spike and water uptake were affected. Based on number of floret drop/spike and floret opening, spikes tinted with Apple green and Classic blue dye solution supplemented with sucrose and citric acid had more acceptability than those tinted with Rose pink and Orange red. The better acceptability of Apple green and Classic blue tinted spikes was associated with more membrane stability index, total soluble protein and total soluble sugar content which decreased with senescence (at the end of vase life). Thus, tinting with Apple green and Classic blue for 1 h in supplemented solution can add colour to tuberose spikes without having any adverse effect on its post-harvest attributes.

Key words: Citric acid, Sugars, Tinting, Tuberose, Value addition, Vase life

All over the world, the floriculture industry has undergone expeditious progress. To entertain the demands in the overseas market, cut-flowers have appeared as an overriding industry. As the flowers are the most perishable horticultural farm produce, there remains some hindrance in proper marketing following standard postharvest management practices by the common farmers. Hence, value addition offers a golden opportunity in product diversification of floral commodities. Tuberose (*Polianthes tuberosa* L.) is an important commercially cultivated crop for cut and loose flowers. It has attractive and fragrant spikes with white flower. The cut flowers of tuberose are used in bouquets and flower arrangements. Tuberose has a great economic potential for flower trade but its limited genetic variability for flower colour reduces its market value. So, tinting tuberose flowers increases its credibility as the market value of tinted spikes is higher than spikes with white flowers. Tinting enhances aesthetic beautification also.

Coloring with food dyes at different concentrations also make flowers vulnerable to post-harvest losses. Thus, maintaining the keeping quality of cut flowers and enhancement of their vase life after tinting are highly desirable areas of floricultural research. The post-harvest quality of flowers is dependent upon stored metabolic reserves in the form of carbohydrates, fats and proteins (Singh and Srivastava 2006). So, the post-harvest keeping quality of cut spikes can be prolonged either by pulsing or holding them in floral preservative containing carbohydrates and inhibitors of microorganism's synthesis and action. This will simultaneously enhance the growth and retard the senescence of cut flowers (Yadav *et al*. 2015). Several studies have been conducted using different food dyes at different concentration, time etc. but studies pertaining to the effect of food colours on morphophysiological and biochemical attributes of tinted flowers yet need to be focused. Thus, keeping all above in view, the studies pertaining to post harvest quality parameters of tinted spikes with an understanding of changes in physiological and biochemical factors due to tinting were carried out.

MATERIALS AND METHODS

The plants of tuberose cv Prajwal were raised at the Research Farms of Punjab Agricultural University during 2017–18. The spikes were harvested at tight bud stage (when 1-2 basal florets showed colour) and subjected to pulsing treatments in the dye solutions, viz. Apple green, Classic blue, Orange red and Rose pink @1% alone or

*Corresponding author e-mail: shalini_jhanji@yahoo.com

supplemented with sucrose (2%) and citric acid (300 ppm) for 1 h and 2 h. For each treatment, there were three replications and in each replication three spikes were kept. The basal 5-7 cm portion of the spike was dipped in dye solution and after the treatment; spikes were kept in distilled water under ambient conditions. The observations recorded were increase in weight (%), dye solution uptake, opening of floret (%), vase life, and number of florets drop/spike, water uptake and loss in weight. The biochemical analysis for membrane stability index (Premchandra *et al*. 1990), total soluble protein content (Lowry *et al*. 1951) and total soluble sugars (Dubois *et al*. 1956) was carried out from three to four tepals from the middle portion of the spikes. Value addition in ₹ by tinting was calculated as ratio of benefit obtained from tinted spikes to total cost of tinting.

The experiment was conducted in factorial completely randomized design (CRD). Data was subjected to statistical analysis (ANOVA) using SAS software (Version 9.2, SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Vase life is a major concern of cut flowers. The vase life of tinted spikes in Classic blue (T_4) was recorded to be 5.67 days followed by 5.50 days in Apple green (T_1) as compared to 4.50 days in Rose pink (T_7 and T_8, Table 1). The vase life of tinted spikes in Orange red (T_5 andT_6) was at par with T_9 and control (T_{10}). The interaction of dye solution and immersion time was statistically non-significant. Thus, tinting of tuberose spikes could be done without any significant influence on its vase life (Jain *et al*. 2015). The immersion of spikes in Apple green (T_2) for 2 h resulted in significantly maximum uptake of dye (2.28 ml, Table 1). The treatment of spikes in Rose pink (T_7 and T_8) for 1 hr absorbed least amount of dye which was respectively 1.38 ml and 1.35 ml. The spikes tinted for 2 h absorbed more dye (1.63ml) in comparison to 1 h (1.24 ml). Also, the spikes immersed in dye solution with sucrose and citric acid irrespective of type of dye, absorbed more dye. These results could be due to role of sucrose and citric acid

Table 1 Effect of food dyes and immersion time on vase life, dye solution uptake and increase in weight by tuberose spikes (cv. Prajwal)

Treatment (T)	Vase Life (days)			Dye solution uptake (ml)			% increase in weight		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	5.33	5.67	5.50^b	1.65^E	2.02^C	1.83^c	2.43^L (8.96)	3.27^F (10.42)	2.85^f (9.69)
T_2	5.33	5.33	5.33^c	1.45^G	2.88^A	2.16^a	2.91^I (9.82)	3.06^H (10.08)	2.99^e (9.95)
T_3	5.67	5.00	5.33^c	1.55^F	2.02^C	1.78^d	2.95^I (9.88)	2.43^L (8.96)	2.69^h (9.42)
T_4	5.67	5.67	5.67^a	1.68^E	1.98^C	1.83^c	2.72^K (9.49)	3.76^B (11.18)	3.24^d (10.33)
T_5	5.00	5.00	5.00^{cd}	1.52^F	2.12^B	1.82^c	3.45^E (10.69)	3.93^A (11.43)	3.69^a (11.06)
T_6	5.00	5.00	5.00^{cd}	1.82^D	2.12^B	1.97^b	3.13^G (10.19)	3.56^D (10.88)	3.35^b (10.53)
T_7	4.00	5.00	4.50^d	1.38^H	1.55^F	1.46^f	2.14^M (8.41)	3.26^F (10.40)	2.70^h (9.41)
T_8	4.00	5.00	4.50^d	1.35^H	1.65^E	1.50^e	2.85^J (9.71)	2.73^K (9.51)	2.79^g (9.61)
T_9	5.00	5.33	5.17^{cd}	0.00	0.00	0.00	3.06^H (10.08)	3.54^D (10.84)	3.30^c (10.46)
T_{10}	5.00	5.00	5.00^{cd}	0.00	0.00	0.00	3.03^H (10.02)	3.68^C (11.06)	3.37^b (10.54)
Mean	5.00	5.20		1.24^b	1.63^a		2.87^b (9.73)	3.32^a (10.48)	
CD	I = NS T = 0.75 I × T = NS								

*T_1- Apple green; T_2- Apple green+ sucrose (2%) + citric acid (300ppm); T_3- Classic blue; T_4- Classic blue + sucrose (2%) + citric acid (300ppm); T_5-Orange red; T_6- Orange red + sucrose (2%) + citric acid (300ppm); T_7- Rose pink; T_8- Rose pink + sucrose (2%) + citric acid (300ppm); T_9- sucrose (2%) + citric acid (300ppm); T_{10}- Water (Control); *I_1 –Immersion time (1 h); I_2 –Immersion time (2 h); * Different lower case letters horizontally indicate statistically significant difference between immersion times and vertically indicate statistically significant difference between dye treatments. Different upper case letters indicate statistically significant difference between type of dye and immersion time. * Figures in parenthesis are arc sine transformed value

in preventing vascular blockage (Varu and Barad 2010).

The spikes tinted for 2 h showed significantly higher increase in weight (3.32%) than the spikes tinted for 1 h (2.87%, Table 1). The increase in weight increased with immersion time as with time, the amount of solution uptake also increased (Kumar 2014). The increase in weight after tinting with Rose pink (T_7 and T_8) was less than non-tinted spikes indicating poor translocation of the Rose pink dye in the stems as compared to other dyes. The opening of florets is an important post-harvest quality parameter and tinting revealed significant effect on opening of florets (Table 2). The spikes tinted for 2 h showed significantly higher floret opening (40.80%) than the spikes treated for 1 h (37.70%). Concomitant with our results, Kumari *et al*. (2018) also recorded maximum opening of florets in Apple green tinted spikes. The opening of florets was higher in tinting solution with sucrose and citric acid in almost all dyes. This may be due to availability of considerable quantity of respiratory substrate (sucrose) that ensures opening of immature florets and further with increase in immersion time more solutes could be located through xylem (Singh and Kumar 2008).

Floret drop is a prime concern influencing post-harvest quality of tuberose spikes (Table 2).The number of florets drop ranged from 3.01 in control (T_9) to 18.5 in Rose pink (T_7). The floret drop might be due to the interference of dye on osmotic pressure of the cells that altered the cell turgidity or blocked translocation in vascular vessels of the spikes (Chougala *et al*. 2016).The number of floret drop was less in spikes tinted in supplemented solution which could be attributed to more opening of florets due to higher availability of respiratory substrate i.e. sucrose (Varu and Barad 2010). The uptake of water by spikes significantly decreased with immersion time (Table 2). The amount of water uptake was significantly more in spikes tinted for 1 h (50.53 g/spike) as compared to spikes tinted for 2 h (42.30 g/spike). More dye uptake in spikes immersed in dye solution for 2 h accounts for the reduction in amount of water uptake. This might be due to osmotic pressure that controls the movement of water in stem from vase solution. Further the amount of water absorbed was more in all tinted spikes supplemented with sucrose and citric acid indicating the role of citric acid in preventing vascular blockage (Gupta and Jhanji 2020).

The type of dye irrespective of immersion time significantly influenced the % physiological loss as maximum loss was 56.42% with Apple green (T_1) followed

Table 2 Effect of food dyes and immersion time on % opening of floret, number of floret drop , water uptake and loss in physiological weight by Tuberose spikes (cv. Prajwal)

Treatment (T)	% opening of floret			Number of floret drop/spike			Water uptake (g/spike)			% loss in physiological weight		
	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean	I_1	I_2	Mean
T_1	50.87^{B}	53.42^{A}	52.15^{a}	16.35^{D}	14.00^{F}	15.18^{d}	46.47^{H}	46.77^{H}	46.62^{f}	77.63^{A}	35.20^{I}	56.42^{a}
	(45.48)	(46.94)	(46.21)							(61.75)	(36.38)	(49.06)
T_2	43.85^{G}	36.75^{K}	40.30^{d}	7.02^{O}	8.33^{N}	7.68^{i}	56.97^{C}	52.63^{F}	54.80^{c}	52.90^{C}	40.87^{E}	46.88^{b}
	(41.45)	(37.30)	(39.37)							(46.64)	(39.72)	(43.18)
T_3	43.49^{H}	31.29^{O}	37.39^{e}	15.69^{E}	15.67^{E}	15.68^{c}	54.30^{D}	48.63^{G}	51.47^{e}	40.83^{E}	38.57^{F}	39.70^{e}
	(41.24)	(34.00)	(37.62)							(39.70)	(38.37)	(39.04)
T_4	34.95^{L}	37.15^{J}	36.05^{g}	11.02^{L}	13.00^{I}	12.01^{g}	69.63^{B}	52.00^{F}	60.82^{b}	36.43^{G}	54.73^{B}	45.58^{c}
	(36.22)	(37.54)	(36.88)							(37.11)	(47.70)	(42.40)
T_5	21.05^{R}	41.15^{I}	31.10^{i}	13.69^{G}	18.67^{A}	16.18^{b}	36.73^{K}	36.80^{K}	36.77^{i}	16.47^{P}	17.07^{O}	16.77^{h}
	(27.30)	(39.89)	(33.59)							(23.93)	(24.39)	(24.16)
T_6	26.15^{Q}	47.26^{E}	36.70^{f}	13.35^{H}	9.00^{M}	11.18^{h}	44.97^{I}	38.43^{J}	41.70^{h}	28.47^{M}	29.47^{L}	28.97^{f}
	(30.74)	(43.41)	(37.07)							(32.23)	(32.86)	(32.55)
T_7	47.72^{D}	34.85^{M}	41.29^{c}	18.35^{B}	18.67^{A}	18.51^{a}	44.30^{I}	44.97^{I}	44.63^{g}	49.20^{D}	35.67^{H}	42.43^{d}
	(43.68)	(36.16)	(39.92)							(44.52)	(36.66)	(40.59)
T_8	45.02^{F}	48.55^{C}	46.79^{b}	12.02^{J}	17.33^{C}	14.68^{e}	69.43^{B}	53.83^{E}	61.63^{a}	3.30^{S}	32.37^{J}	17.83^{i}
	(42.13)	(44.15)	(43.14)							(10.46)	(34.66)	(22.56)
T_9	34.19^{N}	34.85^{M}	34.52^{h}	3.02^{P}	3.00^{P}	3.01^{j}	70.43^{A}	35.83^{L}	53.13^{d}	21.97^{N}	32.20^{K}	27.08^{g}
	(35.77)	(36.16)	(35.97)							(27.94)	(34.56)	(31.25)
T_{10}	29.69^{P}	42.75	36.22^{g}	11.69^{K}	17.33^{C}	14.51^{f}	12.10^{N}	13.10^{M}	12.60^{j}	5.20^{R}	12.83^{Q}	9.02^{j}
	(33.01)	(40.81)	(36.91)							(13.18)	(20.98)	(17.08)
Mean	37.70^{b}	40.80^{a}		12.22^{b}	13.50^{a}		50.53^{a}	42.30^{b}		33.24^{a}	32.90^{b}	
	(37.70)	(39.64)								(33.75)	(34.63)	
CD	I = 0.01 T = 0.03 I × T = 0.05			I = 0.01 T = 0.03 I × T = 0.05			I = 0.31 T = 0.68 I × T = 0.97			I = 0.02 T = 0.04 I × T = 0.06		

*Details for treatments are given in Table 1. * Figures in parenthesis are arc sine transformed values by 46.88% in (T_2). The least loss was recorded in non-tinted spikes (T_{10}).The spikes tinted for 1 h showed significantly higher physiological loss (33.24%) than the spikes tinted for 2 h (32.90%) irrespective of type of dye used. Among all the treatments, the tinted spikes with Apple green (T_1) for 1 h showed maximum loss (33.24%) and minimum of 3.30% loss in Rose pink (T_8). This loss in weight in vase could be attributed toreduce water uptake with passage of days and utilization of stored reserves (Gupta and Jhanji 2020). The physiological and biochemical parameters were further analyzed to have an insight into the interference of food dyes in metabolism of tepals. Tepals excised from the florets of freshly harvested spikes exhibited high MSI of 40.05. Membrane stability index continued to decrease with increase in immersion time. The MSI was significantly more in spikes tinted for 1 h [29.35 (after tinting, S_1) and 21.65 (at the end of vase life, S_2)] as compared to spikes tinted for 2 h [22.10 (S_1) and 15.28 (S_2)]. The MSI after tinting ranged from 33.58–16.50 and at the end of vase life; the range was from 29.58–12.83. The spikes tinted in supplemented dye solution had higher MSI for all dyes in comparison to spikes tinted with dye alone. The tinted spike in Apple green (T_2) had maximum MSI of 33.58 after tinting but at the end of vase life, the spike tinted with Classic blue (T_4) had MSI of 29.58 which was at par with T_2. This shows that membrane deterioration continues with time and decrease becomes more pronounced with increase in time (Fig 1). This sharp decline in MSI with senescence could be due to loss of membrane integrity which is associated with membrane lipid peroxidation. Earlier studies have also reported loss of membrane permeability with onset of senescence (Chakrabarty *et al*. 2007, Chawla 2008).

During the development of florets, the level of total soluble proteins increased initially but later it declined. Tepals excised from florets of the freshly harvested spikes exhibited high protein content (30.05 mg/g tepal). The spikes immersed for 1 h exhibited significantly higher protein content of 25.94 mg/g (S_1) and 13.71 mg/g (S_2) as compared to spikes tinted for 2 h, 23.88 mg/g (S_1) and 11.56 mg/g (S_2). Non-tinted spikes (T_9) had least protein content after 2 h and spikes tinted with Rose pink (T_7) for 2 h had least protein content of10.23 mg/g petal at the end of vase life. This indicates that there is a gradual decline in protein content of petals towards the end of vase life (Fig 2). This protein degradation might be due to activity of proteolytic enzymes. Among all the proteases in plants, the cysteine protease is more frequent and characterized during senescence (Sidharth and Narendra 2007). Our results were in accordance to decrease of 80% of proteins in the petals of chrysanthemum (Mansnee *et al*. 2013).

Sugars control the plant metabolism, growth and

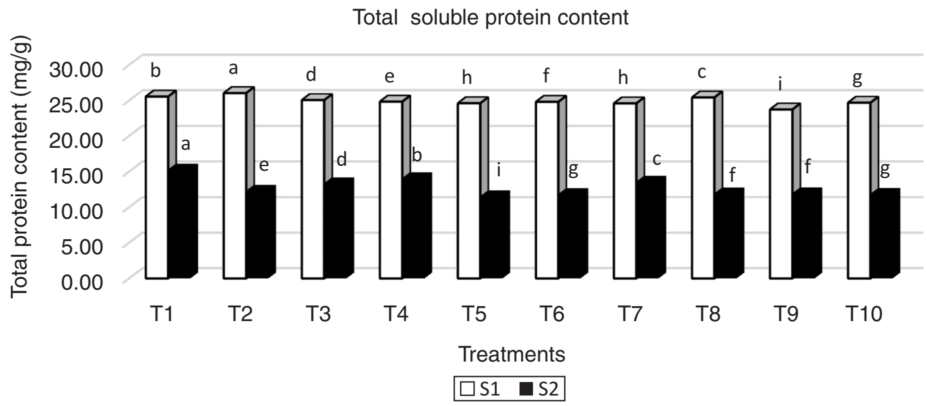

Fig 1 Effect of food dyes and immersion time on protein content (mg/g FW) by Tuberose spikes (cv. Prajwal) during different stages.
*S1- After tinting; S2- At the end of vase life; **T1- Apple green; T2- Apple green+sucrose (2%) + citric acid (300 ppm); T3- Classic blue; T4- Classic blue + sucrose (2%) + citric acid (300 ppm); T5- Orange red; T6- Orange red + sucrose (2%) + citric acid (300 ppm); T7- Rose pink; T8- Rose pink + sucrose (2%) + citric acid ( ); T9- sucrose (2%) + citric acid (300 ppm); T10- Water (Control); ** *Different lower case letters indicate statistically significant difference between dye treatments.

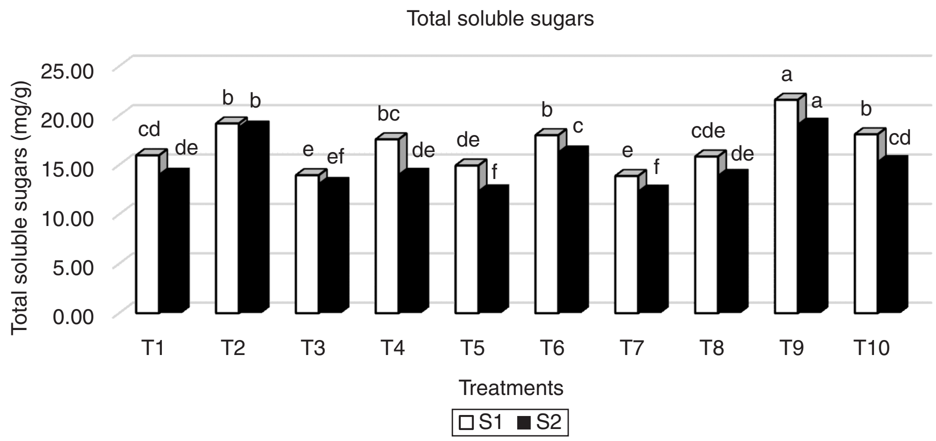

Fig 2 Effect of food dyes and immersion time on total soluble sugars (mg/g FW) by Tuberose spikes (cv. Prajwal) during different stages.
*S1- After tinting; S2- At the end of vase life; **T1- Apple green; T2- Apple green+ sucrose (2%) + citric acid (300 ppm); T3- Classic blue; T4- Classic blue + sucrose (2%) + citric acid (300 ppm); T5- Orange red; T6- Orange red + sucrose (2%) + citric acid (300 ppm); T7- Rose pink; T8- Rose pink + sucrose (2%) + citric acid (300 ppm); T9- sucrose (2%) + citric acid (300 ppm); T10- Water (Control); *** Different lower case letters indicate statistically significant difference between dye treatments.

development and are correlated with light, stress and hormone signaling (Singh and Kumar 2008). The tepals of freshly harvested spikes exhibited low total soluble sugar content as compared to spikes supplemented with sucrose. The content of total soluble sugars of floret increases with time. Like proteins, sugar content declined towards the end of vase life. The content was low in spikes tinted for 1 h (16.24 mg/g at S_1 and 16.38 mg/gat S_2) and reached the maximum level in spikes tinted for 2 h (16.38 mg/g at S_1 and 14.95 mg/g at S_2). Tinted spikes supplemented with sucrose significantly increased total soluble sugars of florets over control. This indicates that exogenously applied sugars supplement the endogenous pool of total soluble sugars, thereby increasing the content.The cost of coloured spike is generally higher than white spike in the market. During the normal season the cost of tuberose spike is 3 ₹. So, the benefit cost ratio of tinted spikes was 2.61 for T_1 and $T_3$and 1.96 for T_5 and T_7 in comparison to spikes tinted with respective dye solutions with sucrose and citric acid which has cost benefit ratio of 2.44 for T_2 and T_4 and 1.84 for T_6 and T_8. Further, the cost benefit ratio was more in all tinted spikes without supplemented with sucrose and citric acid in comparison to tinted spikes supplemented with sucrose and citric acid. Artificial colouring of spikes fetches good price in the market and can add value up to 5–10 times (Mekala *et al*. 2012).

The physiological and biochemical evaluation of tinted spikes revealed that the better performance of Apple green and Classic blue dye than other dyes could be due to high MSI, total soluble protein content and total soluble sugars in tepals of spikes tinted with these dyes. All these parameters contributed to lower floret drop/spike; higher opening of florets in spikes tinted with Apple green and Classic blue and supported utility of these dyes in tinting white spikes for value addition. The performance of Orange red and Rose pink tinted spikes was at par or below non tinted spikes in terms of post-harvest quality parameters which could be due to their low MSI, total soluble protein content, total soluble sugars. Further, on an average for one rupee spend in tinting, one can earn a profit of ₹ 1.40 indicating that tinting the spikes of tuberose cv. Prajwal with food dyes is a good remunerative value addition technique especially when the coloured spikes are not available or when a spike of particular colour is required for decorative schemes.

REFERENCES

Chakrabarty D, Chaterjee J and Datta S K. 2007.Oxidative stress and antioxidant acitivity as the basis of senescence in chrysanthemum florets. *Plant Growth Regulator* **53**: 107–15.

Chawla K. 2008. 'Effect of GA3, BAP and refrigerated storage on keeping quality of chrysanthemum (Chrysanthemum morifolium Ramat)'. M Sc thesis. Punjab Agricultural University, Ludhiana, India.

Chougala S, Naik B H, Mathapati S, Savita K H and Shivakumar. 2016. Effect of tinting on florets drop of cut tuberose spikes. *International Journal of Current Research* **8**: 27206–08.

Dubois M, Giles K A, Rebers P A and Smith F. 1956.Colorimetric method for the determination of sugars and related substances. *Analytical Chemistry* **28**: 350–56.

Gupta A and Jhanji S. 2020. Evaluation of tinting induced changes in post -quality attributes of tuberose. *Indian Journal of Horticulture* **77**(1): 179–88.

Jain R, Janakiram T and Kumawat G L. 2015.Studies on post-harvest attributes of tuberose (*Polianthes tuberosa*) cultivars as influenced by tinting with edible colours. *Current Horticulture* **3**(2): 18–24.

Kumar B S. 2014. 'Studies on standardization of dye concentration, stage of harvest for tinting and post-harvest keeping quality of Tuberose (cv. Suvasini) and Gladiolus (cv. White Prosperity'. M.Sc. thesis, YSR Horticultural University, Rajendranagar, Hyderabad.

Kumari S, Deepika, Raghupathi B, Sarika K and Deb P. 2018. Value addition of tuberose (*PolianthestuberosaL.*) cv. Calcutta Double cut flower by colouring with edible dyes. *Chemical Science Review and Letters* **7**(25): 158–64

Lowry O H, Rosebrough N J, Farr A L and Randall R J. 1951. Protein measurement with the folin phenol reagent. *Journal of Biology Chemistry* **193**: 265–75.

Mansee K, Mukherjee D and Seema. 2013. Regulation of lipoxygenase and superoxide dismutase activities and longevity of chrysanthemum cut flowers by ethanol and methanol. *Indian Journal of Horticulture* **70**: 76–81.

Mekala P, Ganga M and Jawaharlal M. 2012.Artificial colouring of tuberose flowers for valueaddition. *South Indian Horticulture* **60**: 216–23.

Premchandra G S, Saneoka H and Ogata S. 1990. Cell membrane stability, an indicator of drought tolerance as affected by applied nitrogen in soybean. *Journal of Agricultural Science Cambrige* **115**: 63–66.

Sidharth K T and Narendra T. 2007. Integrated signaling in flower senescence. *Plant Signaling and Behavior* **2**: 437–45.

Singh K and Kumar R. 2008. Effect of carbon source on vase life and opening of florets in gladiolus spikes harvested at different stages of development. *Journal of Ornamental Horticuture* **11**: 287–89.

Singh V P and Shrivastava G C. 2006. Physiological and biochemical basis of flower senescence. Bhattacharjee S K (eds). *Advanced Ornamental Horticulture* **5**: 105–19.

Varu D K and Barad A V. 2010.Effect of stem length and stage of harvest on vase-life of cut flower in Tuberose (Polianthes tuberose L.) cv. Double. *Journal of Horticulture Science* **5**: 42–47.

Yadav S, Kumar P N, Arora A and Kumar R. 2015. Effect of protease inhibitors on physiological and biochemical changes influencing keeping quality in gladiolus. *Indian Journal of Horticulture* **72**: 92–99.