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Role of beneficial elements in post-harvest vase life of cut flowers

P Subbaramamma and V Vijaya Bhaskar

Abstract
Beneficial elements have improve the post-harvest life of cut flowers by increasing the water uptake, flower diameter, flower fresh matter weight (FMW), spike length/floral stem, maximum flower opening time and reduced the fresh matter weight loss by preventing the membrane leakage and vessel blockage through limitation of microbial growth in vase solution at cut end of the stem. Beneficial elements also extend the vase life of cut flowers by increasing the osmotic adjustment through improvement of RWC, accumulation of proline, total soluble sugars, TSS and soluble proteins in petals. Further beneficial elements improve the vase life by reducing the cell damage as well as production of oxygen free radicals (H_2O_2) and lipid peroxidation by increasing the activities of antioxidant enzymes in petals of cut flowers. Beneficial elements delayed the petal wilting and petal senescence by improving the nutrient content, chlorophyll/anthocyanin pigments, carotenoids and soluble protein contents by decreasing the degradative enzymes, respiratory activity and ethylene production.

Keywords: Beneficial elements, water uptake, fresh matter weight, osmotic adjustment, oxygen free radicals and ethylene production

Introduction

Beneficial elements are available in abundant quantities in soil, but are not essential for growth in most of the plants. Beneficial elements can promote the growth in some plant species particularly under some specific conditions[37]. The use of beneficial elements at lower doses can alleviate the both biotic (pathogens and herbivores) and abiotic (drought, salinity, high temperature, cold, UV stress, and nutrient toxicity or deficiency) stress responses [49]. Additionally, beneficial elements can provide certain functions of essential nutrients, such as the maintenance of osmotic pressure [48] or induce adaptation mechanisms in plants against the adverse environmental conditions [37].

Cut flowers are mostly used to express the appreciation, affection and emotions on various special occasions. There is an increasing demand for cut flowers in the international trade in recent years were due to use of horticultural plants for their therapeutic benefits. Vase life [42, 21, 43, 28] quality of cut flowers is one the most crucial factors for customer satisfaction and repeat purchase. Flowers grown for ornamental purpose must be of high quality to extend post-harvest longevity of cut flowers to increase the marketability and commercial value. Cut flowers are highly perishable and the vase life is mainly influenced by water relations [42, 39, 10, 9, 18], e-status of soluble sugars [30, 7, 39], production of ethylene gas [30, 40, 19, 26] and development of pathogens [10, 9, 26, 47] in vase solutions. Beneficial elements are one among various chemicals used as preservatives to extend the vase life of flowers. The present review is mainly focused on role of beneficial elements on post-harvest longevity, aesthetics and metabolism of cut flowers.

Vase life

Vase life refers to the time period for which the cut flower retains its appearance in a vase. Vase life is determined based on diameter and length of florets, opening of florets, changes in fresh weight of florets, diameter or length of stem or pedicel, senescence pattern, color of the flower petals and duration of the longevity. The change in the concentration of beneficial element aluminium from 50 ppm to 4000 ppm has changed the flower petal colour from pink to blue respectively in Hydrongea [50] due to formation of colloidal complex with delphinidin an anthocyanin pigment present in plant's epidermal and sub-epidermal cells.

The beneficial elements *viz*., Aluminium, Cerium, Cobalt, Lanthanum, Silica, Sodium and Titanium has extended the vase life [45, 42, 21, 43, 28, 6, 10, 18, 32, 22, 52, 23, 33, 34, 4, 49, 7, 39, 8, 15, 27, 35, 20, 47, 44, 5, 55, 51] of various cut flowers on an average from 8-17 days by improving the solution/water uptake [45, 42, 39, 10, 9, 18, 34, 39, 4, 49, 45, 7, 36, 8, 15, 12, 41, 44, 5, 18, 52, 47], bud/flower diameter [45, 43, 38, 42, 40, 7, 20 floral stem/flower fresh matter weight [45, 21, 28, 6, 1, 29, 34, 39, 49, 7, 8, 15, 12, 20, 44, 5, 51], length of the flower stem [38, 7, 12], peduncle diameter [12], stem curvature [7], bud length [12], opening of flower buds [12, 5], maximum number of days for flower opening of basal and upper flower buds [45] by reducing the abnormalities in flowers [52] fresh matter weight loss [6, 9, 52, 34, 49, 5] by preventing the vessel blockage [4] through limiting/no yeast and bacterial growth [10, 9, 26, 47, 55, 18, 8] in vase solution at cut end of the stem. Acero *et al*. (2016) reported that foliar application of potassium aluminium sulfate $[KAl(SO_4)_2]$ twice a day @ 1.5gL^{-1} has extended the vase life[1] and improved the FMW[1] in Sampaguita (*Jasminum sambac* L.). The use of aluminium sulphate in combination with sucrose and ethanol has extended the vase life [46, 14, 11, 13] upto 18 days by increasing the water uptake (37.67mL) [46, 11, 13], flower diameter [46], flower fresh weight [46, 13], spike length [11], delay in maximum floret opening [11] and total soluble solids [13] thereby extending the flower opening time [46, 13] through limiting the bacterial growth [46, 11, 8] at cut end of the stem through acidification of storage solution.

Osmotic adjustment

The treatment of cut flowers with beneficial elements like selenium, cerium, lanthanum and silica has improved the quality of cut flowers by promoting the osmotic adjustment through maintenance of relative water content [12, 30, 29, 10, 9, 39], accumulation of proline content [30], levels of total soluble sugars [30, 7, 39] and total dissolved solids [8] soluble protein contents [30, 10, 7, 34, 44] in petals.

Antioxidant enzyme activity

The quality of cut flowers after harvest was decreased by increasing the transpiration, respiration rates, wilting, abscission and change in colour of petal, carbohydrate level, protein content, loss of antioxidant enzyme activity and increase in membrane permeability. The use of beneficial elements at low concentration has improved the flower quality after harvest by alleviating the cell damage by improving the antioxidant enzyme system and osmotic adjustment. Sodium selenite, cerium nitrate, lanthanum chloride/nitrate, potassium/sodium silicate/nano particles of silica/sodium silicate, has increased the vase life [30, 29, 10, 9, 53, 16, 18, 2, 25, 20] of cut flowers by alleviating cell damage through improvement of relative water content [30, 29, 10, 9, 39] (RWC), activation of antioxidant enzymes [15, 2, 20, 29, 53, 16] *viz*. superoxide dismutase (SOD) [30, 10, 9, 29, 18, 25, peroxidase (POD) [30, 10, 39, catalase (CAT) [30, 10, 9, ascorbate peroxidase (APX) [30, 29, 10, 18], glutathione (GSH)-Ascorbate (ASA) cycle [29, 9, 53, 16, 57], glutathione reductase (GR) [30, 29], dehydroascorbate reductase (DHAR) [30] and monodehydroascorbate reductases (MDHAR) [30] and by decrease in production of malondialdehyde (MDA) [30, 29, 10, 57, 18, 2, 39], polyphenoloxidase (PPO) [10], hydrogen peroxide (H_2O_2) [30, 2] contents and oxidase enzyme [21] activities in petals of treated cut flowers as compared to control.

Cobalt in combination with sucrose and nickel has increased the vase life [23, 36] by decreasing the oxidative stress damage [23] and by improving the membrane stability [23] in flower petals.

The use of silicon nano particles or silica in combination with malic acid (2mM), acetyl salicylic acid (1.5mM) and glutamine in vase solution has significantly improved the vase life by reducing the accumulation of melondialdehyde [24], ACC oxidase activity [24] (decreased the ethylene production), lipid peroxidation [24] and membrane permeability [24] thereby improved membrane stability [24, 39] in cut Lisianthus/Gerbera flowers.

Moreover the use of silica nano particles in combination with Ca-Chelate has increased the phenylalanine ammonia-lyase content [3] in stems, lead to the production of cellulose [3] and lignin [3] materials might helps in an increase in sclerenchymatous tissue in the hypodermis of stem, thereby strengthening and lignification of tissues in stems take place, which eventually decreased the stem bending [3] and petal senescence in cut gerbera flowers.

Nutrient content

Beneficial elements like cobalt, lanthanum and sodium improve the nutrient contents *viz*., N [49], P [41], K [38, 41] Ca [38], Mg [41], Mn [41], Fe [41], Cu [41] and Zn [41] of floral stems/flower petals and delayed the senescence of cut flowers petals of many ornamental species.

Pigments

Beneficial elements cerium, cobalt lanthanum and silica has improved the vase life of cut flowers by increasing the pigments like Chl a [9], Chl b [9], total chlorophyll [9, 49, 7, 24, 39, 8] content, flavonoid [39] and Carotenoid [9, 34] contents in the leaves of treated plants, whereas cobalt in combination with nickel + salicylic acid + sucrose has reduced the loss of anthocyanin [23] content in flower petals.

Hormonal control

The post-harvest quality of cut flowers has decreased due to an increase in production of ethylene harmone and suppression of the activities of auxin and cytokinin harmones. Ethylene causes petal and flower wilting during senescence by inhibiting cell expansion through the regulation of aquaporin [31] proteins that promote water transport through biological membranes [56], subsequently it causes a negative water balance, a key limiting event in the vase life of cut flowers [51]. The beneficial elements selenium, cobalt, silica and sodium benzoate has extend the vase life [30, 40, 22, 26, 19, 17] of ethylene sensitive cut flower species by suppression of ethylene production [30, 40, 19, 26, 19, 8, 17] through regulation of methionine content and by down regulating of 1-amino cyclo propane-1-carboxylic acid (ACC) oxidase enzyme activity respectively. Cobalt regulates the activities of auxin [40] and cytokinin [40] hormones in addition to the stomatal closure [40] thereby maintained the more water potential [40] in flower petals.

Petal senescence

Beneficial elements like cerium, selenium, cobalt, lanthanum, silica retard the wilting [24, 5], petal senescence in cut flowers by maintenance of more total soluble sugars [7, 39] and soluble proteins [10, 7, 34, 44] by decreasing the electrolyte leakage [23, 29, 47], respiration [30], sugar starvation [30] degradation of carbohydrates [24], protein degrading enzyme activities [24, 34] and ethylene production [19].

Table 1: Influence of beneficial elements on extension of vase life of various cut flowers

S. No.	Beneficial element with concentration	Name of the crop	Response	Reference
1.	Al at 50 ppm Al at 400	Hydrongea	Pink in flower petal color Flower petal color changed to blue color it could be attributed to the formation of colloidal complex with delphinidin an anthocyanin pigment present in plant's epidermal and sub-epidermal cells	Trejo-Téllez *et al*. (2016)
	Aluminium sulphate @ 100 ppm	Asiatic hybrid lily cv. Arcachon	The treated Asiatic hybrid lily cv. Arcachon flower buds took maximum number of days for opening of basal (1.83 days) and upper (5.66 days) flower buds, increase in diameter of basal (180.69 mm) and upper florets (167.21 mm), vase life of spike (16 days) and solution uptake (135 ml) as compared to control	Sunita Kumari *et al*. (2018)
	Aluminium sulphate @ 200 ppm in combination with 2% sucrose	Lilium cv. Monarch flowers	Extended the vase life upto 12.8 days as compared to control (9.5 days). The same treatment had recorded the maximum water uptake (37.67ml) by flowers than other treatments. The combined treatment had delayed the opening of first (2.33days) and second (3 days) florets and it also recorded the highest values for flower longevity and diameter of the opened flowers. Maximum flower fresh weight (42.65g) was recorded with aluminum sulphate (200 ppm) alone	Singh *et al*. (2016).
	Aluminium sulphate @ 100 ppm in combination with 2.5% sucrose	Rosa hybrida cv. Black Magic	Extended the vase life upto18 days.	Hajizadeh *et al*. (2012)
	$Al_2(SO_4)_3$ @ 300 ppm+ 20% sucrose	Gladiolus cvs. White Prosperity and Red Beauty and calla lily flowers	Extend the vase life by improving water uptake through limiting the bacterial growth at cut end of the stem by acidification of storage solution, maximum floret opening and increase in spike length.	Gupta *et al*. (2020)
	Aluminium + Ethanol + Sucrose preservative solution	Rose cv Red Sky 'Blizzard	Showed the longest vase life, flower opening, solution uptake, petal fresh weight and TSS values in Rose cv Red Sky than in Rose cv 'Blizzard'	Hailay Gebremedhin *et al*. (2013)
	$Al_2(SO_4)_3$ @100 mg L^{-1}	calla lily flowers	Maintained the best water balance of the calla lily floral stems in solutions with $Al_2 (SO_4)_3$ at early stage (cartridge stage) and 1/3 flower open stage.	Sales *et al*. (2021)
	Aluminium sulphate $Al_2(SO_4)_3$ @300 mgL^{-1}	Rose cv Cherry Brandy	Improved the vase life and post-harvest quality of flowers by maintaining the flower's fresh matter weight.	Jowkar *et al*. (2012)
	Aluminium sulphate $Al_2(SO_4)_3$ @150 mgL^{-1}	Rose cv Boeing	Improved the vase life upto 12 days and flower diameter when compared to water (control) treatment (9 days).	Seyf *et al*. (2012a)
	Aluminium sulphate $Al_2(SO_4)_3$ @150 mgL^{-1}	Lisianthus flowers	Extend the vase life upto 8-15 days. Increased the flower's FMW (fresh matter weight) upto 8 days after the start of the experiment.	Li-Jen *et al*. (2001)
	$Al_2(SO_4)_3$ @ 0.6 gL^{-1}	Rose cv. "Royalty,"	Reduced the FMW loss during the vase period.	De la Cruz-Guzmán *et al*. (2007)
	$Al_2(SO_4)_3$ @ 100 ppm	Tuberose cv single	Extend the vase life upto 12 days.	Mohammadi *et al*. (2012a)
	Foliar application of potassium aluminum sulfate [$KAl(SO_4)_2$] twice a day @ 1.5gL^{-1}	Sampaguita (*Jasminum sambac* L.)	Extended the vase life and improved the FMW	Acero *et al*. (2016)
2.	sodium selenite (Na_2SeO_3) @ 6mg	Easter Lily (*Lilium longiflorum*)	Increased the vase life by alleviating cell damage through activation of ROS scavenging system and by promoting the osmotic adjustment Enhance the vase life by enhancing the activities of superoxide dismutase (SOD), peroxidase (POD), catalase (CAT), ascorbate peroxidase (APX), glutathione reductase (GR), dehydroascorbate reductase (DHAR) and monodehydroascorbate reductases (MDHAR). It improved the relative water content (RWC) and the levels of soluble sugar, proline and soluble protein in petals of Lilium longiflorum cut flowers as compared to control. The sodium selenite (Na_2SeO_3) had remarkably decreased the production of malondialdehyde (MDA) and hydrogen peroxide (H_2O_2) contents in treated flower petals as compared to control. The Na_2SeO_3 had improved the vase life by regulating the antioxidant system and osmotic adjustment ability.	Lu *et al*. (2020).
3.	Cerium: $Ce(NO_3)_3$	Turf grass seedlings	Decreased the MDA content, electrolyte leakage and increased the FMW (fresh matter weight) and DMW (drymatter weight) of turf grass seedlings under Cu stress conditions. Furthermore, cerium had alleviated the oxidative stress damage by regulating the metabolisms of antioxidant enzymes like ascorbate and glutathione under Cu stress.	Liu *et al*. (2016)
	$Ce(NO_3)_3$ @ 40 µM	Lisianthus cut flowers	Recorded the longest vase life upto 15.42 days through improving the water uptake by reducing the microbial load at the stem end and by enhancing the protein contents in flower petals. The same treatment had recorded the lowest malondialdehyde (18.65 nmol g^{-1} fresh weight) content and also showed the lowest polyphenol oxidase (PPO) activity.	Firoozeh *et al*. (2020)

			The activity of ascorbate peroxidase (APX), peroxidase (POD) and antioxidant enzymes were significantly higher in treated cut flowers.	
	Ce $(NO_3)_3$ @ 40 µM	Lisianthus 'Pink Picotte' cut flowers	Improving the vase life of cut lisianthus 'Pink Picotte' flowers by enhancing the ASA-GSH cycle and water retaining capacity and inhibiting the loss of fresh weight by reducing bacterial colony in vase solution and by increasing leaf chlorophyll content. The catalase activity (8.57 IU g^{-1} FW min^{-1}), superoxide dismutase activity, the contents of Chl a, Chl b and Carotenoids were improved in the leaves of the plants treated with Ce $(NO_3)_3$.	Firoozeh Pourzarnegar and Davood Hashemabadi (2020)
	Addition of Ce $(NO_3)_3$ in vase solutions	Cut flowers of rose	Enhanced the flower longevity by increasing antioxidant activity and strengthening of ASA-GSH cycle.	Wang *et al.* (2017)
	Addition of Ce $(NO_3)_3$ in vase solutions	Lilium longiflorum	Enhanced the flower longevity by increasing antioxidant activity and strengthening of ASA-GSH cycle.	Houa *et al.* (2018)
	Treatment with Ce $(NO_3)_3$	Cut flowers of Carnation	Reduced the accumulation of MDA and strengthened the ascorbate and glutathione metabolism in flower petals	Zheng and Guo, (2018)
	Treatment with Ce(NO3)3@300 µM	Strelitzia reginae Aiton Flowers	Ce(NO3)3 has prolonged postharvest longevity of S. Reginae flowers by increasing the solution uptake and SOD and APX activity and decreasing the MDA content. Ce$(NO_3)_3$ reduced the bacterial and yeast populations on cut end of floral stems.	Jahangir Azarhoosh *et al.* (2021)
4.	Cobalt @ 0.1 mM (61.1%) concentration in preservative solution	Lily cv. Star Fighter Lily cv. Star Gazer.	Promoted the longevity of floral stems in lily cv. Star Fighter than the use of cobalt @ 0.2mM (44%) concentration in preservative solution. Improve the longevity of floral stems of lily cv. Star Gazer by 19.7%.	Mandujano-Piña *et al.* (2012)
	Application/use of Cobalt in preservative solution	Cut flowers of roses	Partially inhibits ethylene production, auxins and cytokinins activity. Additionally, it cause stomatal closure to some extent and increases water potential in cut flowers	Reddy *et al.* (1988)
	cobalt @ 2 mM	cut marguerite (*Argyranthemum* sp.) flowers	Extended the vase life upto 5 days than control treatment.	Kazemi (2012)
	Cobalt @1.5mM	Cut flowers of rose (*Rosa hybrida* L. cv. Samantha)	The cobaltous ion (Co2+) @1.5mM extended vase life by1) an increased water uptake into the cut flower, 2) an improved water balance during opening, 3) a delay in loss of fresh weight, and 4) a prevention of the occurrence of bent-neck than at @ 2.0 mM concentration.	Venkatarayappa *et al.* (1980)
	A combination of 2.5 mM Cobalt +2 mM Nickel+2mM salicylic acid with 2.5% sucrose	Lily cv. "Prato"	Increased the vase life in cut flowers of lily cv. "Prato" might be due to an improvement in membrane stability, reduction in oxidative stress damage during flower senescence and also reduced the loss of anthocyanin content in flower petals.	Kazemi and Ameri (2012)
	A combination of $CoCl_2$ ($5x10^{-4}$ M) + sucrose (0.1 M) treatment	Cut chrysanthemum flowers	Extended the vase-life of flowers from 22 and 24 days than other treatments.	Pardha Saradhi and Mohan Ram (1989)
	Application of Co ($100mgL^{-1}$)	Carnation	Retarded the senescence by counteracting with ethylene production.	Jamali and Rahemi (2011)
	Application of cobalt chloride ($CoCl_2$) @ 300 mgL^{-1} Application of cobalt chloride ($CoCl_2$) @ 400 mgL^{-1}	Tuberose	Extended the vase life by 10.66 days and water uptake by 1.53 mLg^{-1} FMW) and reduced the FMW loss by 19.99g in tuberose. Increased the carotenoid (0.40 g) and protein (31.10%) contents by decreasing the peptidase activity in petals.	Mohammadi *et al.* (2012b)
	Application of $CoCl_2$ (200 mgL^{-1}) in vessel solution	Roses	Maintained a high rate of water flow through stems as well as high water uptake by flowers in cut roses through inhibition of vessel blockage in stems.	Aslmoshtaghi *et al.* (2014)
	Application of cobalt @ 0.3 mM	Gladiola (Gladiolus grandiflorus Hort.) cv. Borrega Roja.	Significantly increased water absorption by flower stems, while the lowest percentage of weight loss was recorded in fresh rods treated with of Co. Furthermore, the low concentrations of Cobalt had significantly increased N content in stems and chlorophyll content in leaves. The high total dry weight of leaves and stems was recorded with 0.3 mM of Cobalt treatment	Trejo-Téllez *et al.* (2014)
	Loading of flowers with high concentration of $NiCl_2$ or $CoCl_2$ (1000-1500 ppm) for a short period of (10-15 minutes) time	Aster, Gerbera, Gladiolus, Tuberose, Carnation, Chrysanthemum, Phalaenopsis and Snapdragon cut flowers	Helpful in reducing the attack of microbes and ethylene synthesis.	Lakshman *et al.* (2014)
5.	Application of Lanthanum at 10 and 20 µM concentrations	Tulip (*Tulipa gesneriana* L.) cv. "Ile de France,".	Promoted the flower diameter and length of the floral stem in tulip (*Tulipa gesneriana* L.) cv. "Ile de France". It also stimulated the accumulation of Ca, K, and La itself in the same ornamental species.	Ramírez-Martínez *et al.* (2012)
	Application of Lanthanum	Cut Easter lily flowers	La had significantly increased the activities of antioxidant enzymes, while decreasing the concentrations of reactive oxygen species, as compared to the control.	Aide and Aide (2012)

	Application of beneficial nutrient lanthanum (La) as $LaCl_3$ and $La(NO_3)_3 \times 6H_2O$ @ 40 µM each	Tulip cultivars (*Tulipa gesneriana* L.)	Both the treatments increased the bud length, diameter, stem length and stem curvature in tulip cultivars. Out of 15 tulip (*Tulipa gesneriana* L.) cultivars tested, the cultivars Laura Fygi and Rosario had registered the highest relative stem elongation, whereas Lalibela and Acropolis cultivars had displayed the greatest stem curvature on the last day in vase solution with the two sources of lanthanum treatment. The highest solution uptake was recorded in flower stems treated with $LaCl_3$ over the control by 5, 11, 15, 18 and 24% at 3, 5, 7, 9 and 11 days after cutting respectively. The relative stem elongation and solution uptake rates were high in flowers treated with $LaCl_3$ (35.2% and 1.71mL respectively) and La $(NO_3)_3 \times 6H_2O$ (35.5% and 1.54mL respectively) treatments than in control (21.3% and 1.44 mL respectively) and ascorbic acid (27.4% and 1.44 mL respectively) treatments. The variety Laura Fygi recorded the longest vase life upto 13 days with lanthanum treatment. The higher amounts of total soluble sugars in petals and total soluble proteins in leaves were found in La-treated stems at the end of the vase life period as compared to the AsA and control treatments. Additionally, La $(NO_3)_3 \times 6H_2O$ supply had increased the fresh weight of stems in vase and prolonged the vase life. Moreover, this treatment had resulted in the highest foliar concentration of chlorophylls at the end of vase life.	Fernando *et al.* (2020)
6	Addition of (0,100, 150, and 300 mgL-1) potassium silicate (K_2SiO_3) @ 300 mgL^{-1} in preservative solution	Carnation cut flower cv. "Harlem"	Improved the vase life as a result of a significant reduction in ethylene production.	Jamali and Rahemi (2011)
	Application of 2.5 mM Si together with 3 mM acetylsalicylic acid	Carnation flowers	Reduced the wilting, retards chlorophyll and carbohydrate degradation and reduced the activity of oxidase enzymes.	Kazemi *et al.* (2012)
	Addition of silica nanoparticles (SiNPs) to preservative solutions (0, 1, 2, and 3 $mg \cdot dm^{-3}$) @ 2 $mgdm^{-3}$	Roses	Increased the flower longevity by improving relative fresh weight, relative water content (RWC) and water uptake by flowers than in control treatment. The enhancement in chlorophyll content, total soluble sugars, as well as total phenol and flavonoid contents were positively correlated with SiNP treatments. Malondialdehyde (MDA) content was significantly decreased and retained the membrane stability in SiNP treated roses than in control roses. Activities of peroxidase (POX) and polyphenol oxidase (PPO) enzymes were significantly increased in SiNPs treated roses than in untreated roses.	Rasha Elserafi, (2019)
	Application of nanoparticles of silicon (40mgL-1) in vase solution The use of silicon nanoparticle (40 mgL-1) in combination with silver nanoparticles (40 mgL-1)	Lisianthus cut flowers	The average vase life was extended to about 17 days with nanoparticles of silicon (40mgL^{-1}) in vase solution than in control treatment (about 5 days). The same treatment had increased the relative fresh weight, solution uptake, total chlorophyll content and total dissolved solids in treated flowers. Microbial proliferations were not observed by application of nanoparticles of Silicon (40 mgL^{-1}). Inhibited the ethylene signaling thereby commercially increased the vase life of Lisianthus cut flowers.	Fereshteh *et al.* (2017)
	The combined application of (20 mgL-1) nanoparticle-SiO2 and (240 mgL-1) Ca-Chelate Application of nanoparticle-SiO2 (80mgL-1) along with Ca-Chelate (240 mgL-1) Use of calcium chelate (60 mg L-1).	Gerbera Flowers	Recorded the lowest stem bending (deviation angle of 8.78°). Increased the lignin and cellulose contents by 33 and 15% respectively than in control treatment. Recorded the highest amount of phenylalanine ammonia-lyase (2.87 units per mg of fresh leaf) activity. The hypodermis (sclerenchyma) developed beneath the epidermis had strengthened the stem tissue. Application of Silica nanoparticles and calcium chelate had increased the phenylalanine ammonia-lyase content, showed its effect on production of cellulose and lignin materials which helps in an increase in sclerenchymatous tissue in the stem, led to strengthening and lignification of tissue in stems which eventually decreased the stem bending in gerbera flowers.	Alikhani *et al.* (2021)
	The combination of silicon (1.5mM), malic acid (2mM) and acetyl salicylic acid (1.5mM) in vase solution	Cut Lisianthus flowers	Significantly reduced the melondialdehyde accumulation and ACC oxidase activity, while it improved membrane stability in cut Lisianthus flowers.	Kazemi *et al.* (2012)
	The combination of silicon, acetylsalicylic acid and glutamine in vase solutions	Gerbera cut flowers	Increased the water absorption, fresh weight and vase life, while decreasing the MDA content, ACC-oxidase activity and membrane permeability together with total delay in senescence and lipid peroxidation in gerbera cut flowers.	Kazemi *et al.* **(**2012)
	Addition of silicon (5mM) in vase solution	Narcissus tazetta cut flowers	Improved the relative fresh weight by 16% and total water uptake by 27% as compared to control (day 7 of the experiment). In Narcissus tazetta cut flowers. Silicon (5mM) treatment had also increased fresh weight of	Hassan Bayat and Mohammad Hossein

			flower (excluding stem) from 0.185 to 0.259 g (40% increases). The application of Si (5mM) had extended the vase life of cut flowers by 2.66 days in comparison to control.	Aminifard (2018)
	The highest dose (800gL^{-1}) of Silicon	Roses	Recorded the best values of stem diameter (0.5 mm) and floral bud length (1.9mm) than in control treatment. The weight and length of the stem and the peduncle diameter were improved regardless of the dose and method of silicon application. The stems that received the Si treatment had showed the reduced fresh mass variation, maintenance of greater relative water content in petals and leaves and greater index for opening of floral buds. The peroxidase (POD) activity was also reduced with Si supplementation. The petals with higher POD activity showed reduction in color parameters. The Si supplementation (800 gL^{-1}) not only favours the quality of rose stems at better harvest, but also provides a conservation of postharvest vase life of roses.	(Geerdink *et al*. (2020)
	Pre and Postharvest application of silicon	Two cut peony (Paeonia lactiflora Pall.) cultivars, 'Taebaek' and 'Euiseong'.	The preharvest silicon treatment, had remarkably increased the relevant growth attributes, *viz*., the shoot and leaf lengths, stem and bud diameters as well as the leaf width. In the postharvest storage, the addition of silicon to the holding solution in the vase was able to significantly extend vase life, delay fresh weight decrease, and improve vase quality, as characterized by the antioxidant enzyme activities and mechanical stem strength.	Jinnan Song *et al*. (2021)
7.	Application of NaCl (1gL^{-1}) in irrigation water	chrysanthemum (Chrysanthemum x morifolium Ramat.) cut flower	Improved the quality of chrysanthemum (Chrysanthemum x morifolium Ramat.) cut flower.	Lee and van Iersel (2008)
	Application of sodium benzoate (250 mg L^{-1})	Roses cv. Avalanche	Improved vase life in cut rose cv. "Avalanche" by reducing the ethylene production.	Imani *et al*. (2012)
	Application of 20 µM of sodium nitroprusside (SNP)	Rose	Increased the vase life in rose.	Nazirimoghaddam *et al*. (2014)
	Application of 50 µM of sodium nitroprusside (SNP)	cut rose cv. "Utopia"	The treatment of cut rose cv. "Utopia" with 50µM SNP had recorded the higher amounts of soluble protein content and also improved the solution uptake rate by flower stems thereby improved the FMW ratio as well as extended the vase life from 11 to 13.3 days than in control flowers.	Seyf *et al*. (2012b)
	The application of NaCl (200 mM)	Purple top Vervain	Enhanced the Mn contents in leaves, but neither P, K, Mg, Cu, Zn, and Fe contents nor the flower initiation was affected.	Salachna and Piechocki (2016)
	Pulse solution having sodium silicate (100 mg/L)	cut chrysanthemum (*Dendranthema grandiflorum* L.) flowers	Treatment of cut chrysanthemum (*Dendranthema grandiflorum* L.) flowers with pulse solution having sodium silicate (100 mg/L) had extended the vase life upto 4.46 days than in control treatment. In addition, the flowers pulsed with sodium silicate had exhibited higher SOD activity as compared to control	Kazemipour *et al*. (2016)
	The treatment comprised of NaOCl (0.6 mLL^{-1}) as pulsing solution biocide	Cut flower stalks of rose	Prolong the vase life of the cut flower stalks upto 15.80 days as compared to ordinary tap water treatment. The same treatment had recorded the smallest value for solution turbidity in rose cut flower stalks indicated the less bacterial proliferation or accumulation of plant exudates than in control. The amount of water passed through 5 cm long excised stem sections was high in stalks pulsed with NaOCl than stalks pulsed with $Al_2 (SO_4)_3$ and water.	Tilahun *et al*. (2015)
	Vase solutions containing sodium dichloroisocyanurate dihydrate (Na-DCC) Vase solution with Na-DCC + sucrose	'white friendship' cut gladiolus inflorescences	Vase life, inflorescence postharvest development, fully-open flowers, fresh mass and water balance of white friendship' cut gladiolus inflorescences were high in stalks treated with the vase solutions containing sodium dichloroisocyanurate dihydrate (Na-DCC) treatment as compared to other treatments under ambient conditions. Improved the water balance, number of open flowers and reduced the number of wilting flowers as well as fresh mass loss.	Casares *et al*. (2017)
8.	Foliar application of Titanium-ascorbate (25, 50, 75, and 100 mg L^{-1})@ 75 mg L^{-1}	Geranium cv. "Elite Cherry", petunia (Petunia x hybrida hort. ex E. Vilm.) cv. "Celebrity White," pansy (*Viola x wittrockiana* Gams.) cv. "Delta Premium Marina", and snapdragon (*Antirrhinummajus* L.) cv. "Montego	Titanium-ascorbate @ 75 mg L^{-1} Improved the plant height	Whitted-Haag *et al*. (2014)

		Purple”		
	Application of Titanium ions (8 mg/L)	Gerbera flowers	Extend the longevity of gerberas and also possess the broad-spectrum antibacterial properties. Plate colony counts showed 1700 times less bacteria in vase solution than in control group vase solution	Xia Li *et al.* (2019)

Conclusions
Beneficial elements *viz*., aluminum, cerium, cobalt, lanthanum, sodium, selenium, silicon and titanium have been shown to have beneficial effects in some species of model and cultivated plants. The beneficial elements at low concentrations not only improved the postharvest quality of cut flowers, but also involved in absorption of other nutrients, and activation of defense mechanisms against biotic (pests and diseases) and abiotic stress resistance or tolerance to oxidative stress damage created during petal senescence. Nowdays the flourists, traders and farmers are facing greater challenge towards the extension of vase life of ethylene sensitive cut flowers in a cost effective manner. The research on use of beneficial elements in extension of vase life cut flower is under infancy. So, the knowledge on how beneficial elements extend the vase life by regulating various molecular and metabolic activities in cut flowers is highly essential.

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