A Seminar Paper on
Post-harvest management approaches for vase life improvement of cut flowers

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Post-harvest management approaches for vase life improvement of cut flowers[1]

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ABSTRACT

Cut flowers have become an export income in the global floriculture market. Each type of cut flower has a different vase life. The cut flowers quality and post-harvest longevity depend on senescence delaying factors. Increased temperature & humidity, decreased water uptake, increased transpiration, increased respiration, lower carbohydrate supply and endogenously accumulated or exogenously applied ethylene gas are the various post-harvest factors which reduces vase life & most of them the factors are inter-related. The post-harvest behaviour of flowers is an outcome of the physiological processes. Post-harvest operations may include pre-cooling, storage condition (dry storage, wet storage, controlled atmospheric storage or hypobaric storage), sorting & grading, packaging & transportation. Preservative treatments along with the post-harvest operations may act independently to affect the senescence and vase life of cut flowers. Most of the preservative solution possess water, sugar, germicide, plant growth regulators (cytokinin, Gibberellic acid, abscisic acid), essential oil and combinations of them and control the inhibiting post-harvest factors of mentioned above. Depending upon purpose of the preserving specific cut flowers, conditioning, bud opening development solution, pulsing solution, impregnation & finally holding solution are the preservative treatments done after harvesting which contains carbohydrate in various concentration.

Key words: Vase life, Cut flowers, Post-harvest factors, Post-harvest operations, Preservative treatments

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CHAPTER I

INTRODUCTION

Cut flowers are the flowers or their any parts (buds, flowers, stems, colorful stalks) that have been cut from the plant bearing which includes both fresh and dried preserved plant material (Scoggins, 2014; De and Singh, 2016). Typical application of cut flowers are garlands, wreaths & vase arrangements. Cut flowers occupy an important position as it has importance as a source of national income, in the local and foreign markets. According to *Cut Flower Market Size, Share and Growth Report, 2023-2031,* the global industry of cut flower was valued at US$ 30.9 billion in 2022. It is estimated to grow at a Compound annual growth rate of 6% from 2023 to 2031 and reach US$ 52.0 billion by the end of 2031. Alstromeria, roses, bird of paradise, carnation, lavender, lilies, sunflower, gladiolus, gerbera, and etc. are taking place in global market.

The vase life of cut flowers is the extended survival of cut flowers in a vase; affected by several preharvest and postharvest conditions (Nguyen and Lim, 2021). It is one of the quality traits as it represents amount of time spent and the conditions that flowers experience while in transit from farm to end user (Banjaw *et al*., 2017). Flowers are highly perishable unlike other horticultural crops. The post-harvest behavior of flowers is a result of the physiological processes, occurring in stem, flower bud, leaves, leafless peduncle or scape connecting bud to the stem (Kumar *et al*., 2022). So, post-harvest management is very crucial for cut flowers if we want to extend its vase life and reduce post-harvest losses significantly. For increasing the post-harvest life of flowers, we should know about the factors that affect post-harvest life, so that we can provide required condition to plant. Postharvest life will be increased if temperature, humidity, water relations, respiration, transpiration etc. factors are properly maintained.

Flowers continue to function metabolically even after being harvested, which depletes carbohydrates, increases temperature and respiration rates, speeds up microbial attack, causes water stress, and increases ethylene accumulation. All of these actions cause the cut flowers to degrade, which in turn lowers the fresh produce's shelf life. The requirement for the proper post-harvest handling technologies develops like so (Nowak and Rudnicki, 1990). After harvesting, there are some important operations like pre-cooling, sorting & grading, storage, packaging, transport, adding preservatives in several ways etc. which are known as post-harvest operations.

The fresh condition of cut flowers is maintained by the use of a post-harvest preservative solution, to provide fresh flowers with a long vase life to the final customer (Nguyen and Lim, 2021). An ideal preservative solution contains sucrose (a respiratory substrate for nourishment), a biocide or germicide (intended to kill bacteria), an acidifier (to lower the pH of the solution & to improve absorption), and anti-ethylene chemicals {viz., alpha - aminooxyacetic acid (AOA), Aminoethoxyvinylglycine (AVG), 1-methylcyclopropene (1-MCP), etc to minimize the damage from ethylene}, etc. Optionally, growth regulators (especially kinetins, Benzylaminopurine, gibberellins), mineral ions (which facilitates solution uptake) could be added in the solutions (Kumar *et al*., 2022). Cut flowers gathered during the bud stage are able to open due to the exogenous application of the sucrose, which gives them the substrates for respiration they vitally need. (Pun and Ichimura, 2003). There are 5 preservative treatments that can be practiced for prolonging cut flower vase life: conditioning, impregnation, bud opening, pulsing, and lastly holding solutions. Conditioning is done to restore turgidity of cut flowers at post-harvest. Bud opening treatment is done for opening immature buds of flowers with help of lower concentration of sucrose. Pulsing solution is very effective globally where higher level of sucrose along with short duration (16-24 hrs) exposure is maintained. Impregnation is done for controlling microbial growth. Apart from specific treatment, various types of holding/ vase solution with 0.5-1% level of sucrose is used globally (Gupta and Dubey, 2018; Nguyen and Lim, 2021).

By considering the above situation, the objectives of this review paper are-

1. To describe the factors which affect post-harvest life of cut flowers
2. To illustrate various post-harvest operations & preservative treatments which increases vase life of several cut flowers.

CHAPTER II

MATERIALS & METHODS

This seminar paper is exclusively a review paper. It is primarily based on secondary sources. Therefore, all the information was collected from secondary sources with a view to preparing this paper. Information is gathered from related e-books, different journal articles, statistical yearbooks, and websites that are accessible online. Constructive feedback from my major professor and course instructors helped me improve this paper. After gathering all relevant information, it was compiled and logically presented in its current form.

CHAPTER III

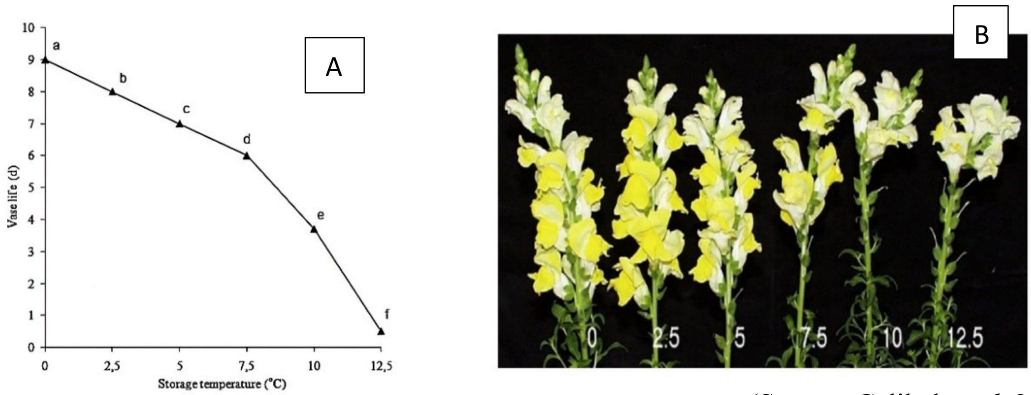
REVIEW OF FINDINGS

3.1 Post-harvest factors influencing vase life

3.1.1 Temperature

The overall keeping quality of the flowers is greatly influenced by the environment (temperature, relative humidity, and gaseous composition) of the location where they are handled (Kumar *et al.*, 2022). At higher temperatures, the rate of senescence and the opening of flower buds both accelerate. Low temperatures result in decreased respiration, less ethylene production from flowers, and, if microorganisms do not multiply more quickly, slower multiplication occurs. The most important metabolic process is respiration that increases with increase in temperature (Gupta and Dubey, 2018). Tropical and subtropical flowers are sensitive to chilling temperatures; such species cannot be stored below a critical temperature ranging from 0 to 13°C. Near 5°C temperatures are typically more effective in causing chilling symptoms in most horticultural products. The recommended temperature range for *Alpinia sp., Strelitzia sp., and Heliconia sp.* is between 10 and 13 °C. (Jaroenkit and Paull, 2003; Costa *et al*., 2010).

Celikel *et al* (2010) studied that, as the storage temperature increased from 0 to 12.5˚C, the vase life of rocket snapdragons that had been stored dry for 5 days at different temperatures fell gradually.



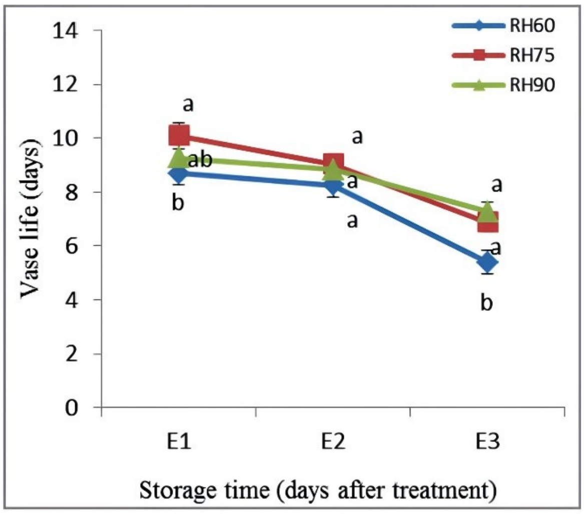
(Source: Celikel *et al,* 2010)

Figure 1. A. Vase life of ‘Rocket’ snapdragon (*Antirrhinum majus* L.) flowers stored dry at different temperatures for 5 days. B. Flowers of ‘Rocket’ snapdragon (*Antirrhinum majus* L.) stored for 5 days at different temperatures then placed in the vase life room (20˚C) for 4 days.

According to Cevallos and Reid (2001), the vase life of cut gillyflowers, narcissuses, irises, chrysanthemums, roses, and tulips does not change when the plant is conditioned in water or dry and the storage temperature was provided between 0 and 10°C.

3.1.2 Humidity

Relative humidity depends on both the amount of moisture available and air temperature. Chamani and Wagstaff (2018) did three different experiments (E1, E2 and E3) using three relative humidity (RH) (60, 75 and 90%). The highest and significant vase life was found in flowers placed in 75% RH. However, 75% relative humidity had no significant differences with flowers placed in 90% RH. The highest reduction was happened in 60% RH. Mean comparison in three experiments also revealed that with increase in storage time in cold room, flower vase life was decreased.



(Source: Chamani and Wagstaff, 2018)

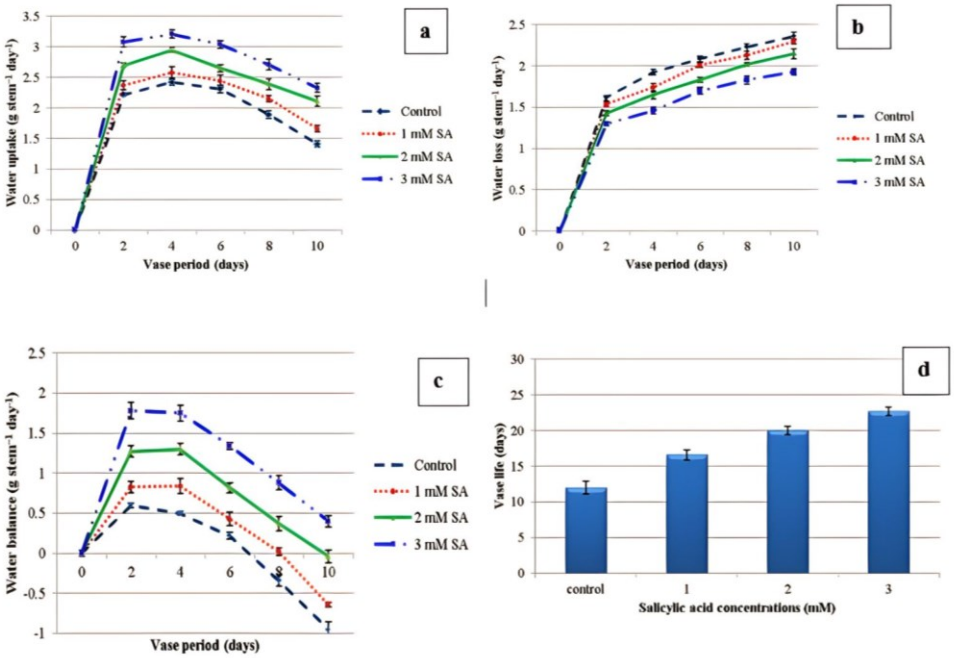
Figure 2. Effects of three different RH on vase life of cut rose flowers in 3 different experiments.

Cut flowers should be kept at 90-92% relative humidity for maintaining turgidity i.e. beneficial for prolonging the vase life of cut flower during post-harvest (Doi *et al.,* 2000).

3.1.3 Water relations

Cut flowers and foliages may have reduced commercial value since they dry during vase life due to poor water uptake (Emongor, 2004). Even when immersed in water, cut flowers and foliages suffer from water deficiencies. (Halevy and Mayak, 1979; van Doorn and de Witte, 1994). Occlusion in the xylem, air embolism (cavitation) (van Doorn and de Witte, 1994), lignification and formation of suberin in the cut end of flower stem (Celikel and Reid, 2002) are the important factors that affecting water relation and water uptake in cut flowers.

Soleimany-fard *et al.*, (2013) studied about treated (sprayed) and untreated cut flowers kept in vase solutions containing salicylic acid at 0.0 (only distilled water), 1, 2 and 3 mM. Sucrose at 4% was added to all treatments as a base solution. The changes in water uptake, water loss, water balance & vase life were estimated during vase period.



(Source: Soleimany-fard *et al.*, 2013)

Figure 3. Effect of post-harvest applications of different concentrations of salicylic acid on a. water uptake, b. water loss, c. water balance & d. vase life of cut alstroemeria flowers.

The result showed in Figure 3a, that the water uptake increased significantly during the first 4 days after harvest and from this time until end of the experiment decreased significantly. The higher the salicylic acid concentration applied, the greater the improvement in water uptake. Highest water uptake values were observed in 3 mM salicylic acid treatment. Salicylic acid can decrease pH of holding solution and so, the growth and proliferation of bacteria was reduced, which causes increase of water uptake (Raskin, 1992). In figure 3b, the lowest levels of water loss were observed for 3 mM salicylic acid treatment during vase period, followed by 2 mM and 1 mM salicylic acid treatments while the highest was in control treatment. It was assumed that the effect of salicylic acid treatment on higher concentration, water loss could be less due to the increasing water uptake (Raskin, 1992) as well as decrease in transpiration rate (Mei-hua *et al.*, 2008).

In figure 3c, during vase period, the decrease in water balance of cut flowers in association with a lower water uptake and high-water loss. Water balance was determined by the difference between water uptake and water loss from leaves of cut flowers (Ha *et al.*, 2017). Among the studied treatments, 3 mM salicylic acid treatment had the highest amount of water balance. It can be concluded by figure 3d, that using salicylic acid treatment (3mM) significantly increased the vase life cut alstroemeria flowers, as compared to control treatment.

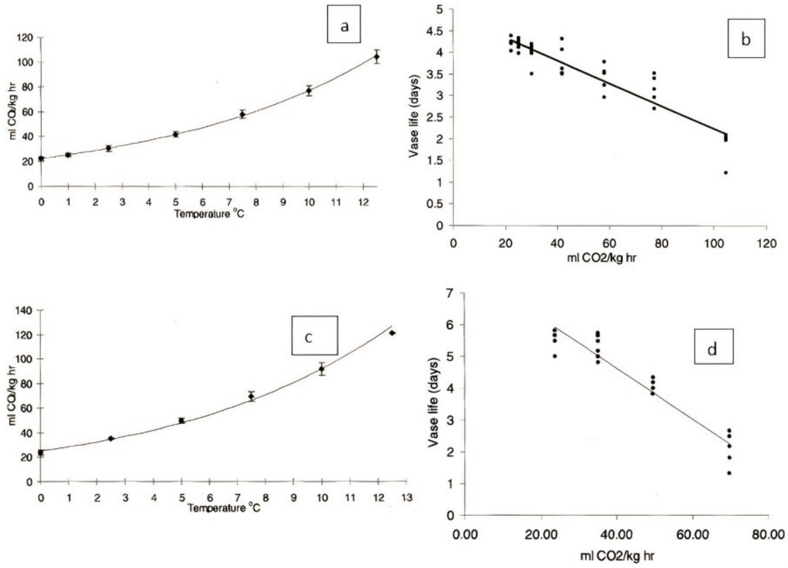
The internal metabolic processes (respiration, transpiration, and ethylene accumulation), which continue to exist in the flower system long after harvest, would be significantly influenced by water relations. To improve water relations of cut flowers, recutting the stems in water, quick hydration (conditioning), maintenance of cool chain should be practiced (Kumar *et al.*, 2022). Acidification of water and addition of wetting agent and preservatives in the holding solution improve water uptake of cut flowers markedly (Gupta and Dubey, 2018). Vase life of gladiolus decreases when the concentrations of salts in water approaches 700 ppm and in chrysanthemums and carnation 200 ppm is harmful (Waters, 1968).

3.1.4 Transpiration

Higher the humidity in the air, less is the transpiration rate and vice-versa. Water stress and flower wilting are outcomes of an increased transpiration rate. When transpiration exceeds water uptake or absorption, wilting and water deficits take place. In post-harvest deterioration, carbohydrates become depleted because of higher respiration rates, membrane stability index (MSI) declines because of microbes, water stress, as well as increased ethylene accumulation. (Kumar *et al*., 2022). Lu *et al* (2010) found that, silver nanoparticles treatments tended to inhibit transpiration from leaves and suppress decrease in hydraulic conductance of cut stems of rose. Reducing transpiration can also improve the water balance of cut flowers and so it extends vase life of Rosa hybrida ‘Movie Star’.

3.1.5. Respiration

The rate of respiration is affected by the amount of carbohydrates present in the harvested cut flowers, temperature, and the usage of specific chemicals to control it. With higher temperature, there is faster rate of respiration and burning of the tissue (Cevallos & Reid, 1998). Cevallos & Reid (1998) found out that two cultivar of *Narcissus* flower (paperwhite & jonquil) showed rapid increase of respiration with the increase of dry storage temperature. Consequently, the life of flowers were shortened in both cases.



(Source: Cevallos and Reid, 1998)

Figure 4. Effect of temperature on the respiration rate of a. Paperwhite *Narcissus* & c. Jonquil *Narcissus* & vase life of b. Paperwhite *Narcissus* & d. Jonquil *Narcissus* in dry storage.

Different preservatives can have potentiality to inhibit respiration activity. The senescence of the flowers in *Consolida ajacis* is associated with the increase in ethylene production and respiration. When cut flowers of *Consolida ajacis* were pulsed with 1-mM silver thiosulphate (STS) or 1-mM STS+5% sucrose, it partially inhibited respiration activity, thereby prolonging the flower vase life (Finger *et al.*, 2004).

3.1.5. Carbohydrate supply

Unlike fruits & vegetables, flowers can be cut in the bud stage. In some flowers this is normal commercial practice (Rose, Gladiolus, Lilies); in others, flowers are normally cut near fully open(Chrysanthemum, Gerbera). A fully developed rose flower's dry weight is more than double that of a harvested bud, yet the flower stem cannot supply all of the materials required to generate this increase in dry weight. Fortunately, it is possible to supply the requisite additional carbohydrate by adding it into the solutions in which flowers are held. It can increase the thickness and lignification of the vascular tissues of cut flowers (Lopez and Barclay, 2017). Moreover, sucrose can affect stomatal closure and reduce water loss (Kottapalli *et al.*, 2018). Bud opening, pulsing & holding solution are the treatments which contains carbohydrate in various concentration (Reid and Kofranek, 1980).

3.1.6. Ethylene gas

Ethylene is a hydrocarbon gas, and commonly known as a ripening hormone which induces senescence in flowers (Gupta and Dubey, 2018). Cut flowers are less affected by endogenous or exogenous ethylene since this gas speeds up the flower's aging process. (Koohkan *et al.,* 2014). Flowers can show high, low sensitivity or insensitive towards ethylene. Some important effects of ethylene are: sleepiness of petals in carnation, epinasty in poinsettia, abscission of petals or whole flowers, inhibition or promotion of bud opening in flowers (Gupta and Dubey, 2018).

Table 1. Different A. high & low sensitive cut flowers B. insensitive cut flowers towards ethylene gas

A.

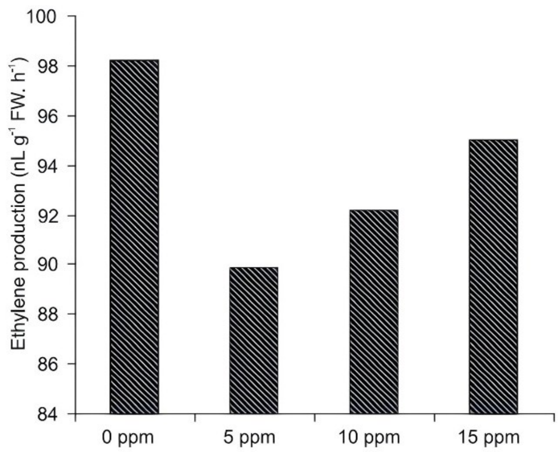
Highly sensitive	References	Low sensitive	References
Alstroemeria	Wagstaff *et al*.(2005)	*Anthurium*	Muraleedharan (2020)
Consolida ajacis (Dephinium)	Santos *et al*. (2005)	Gerbera	Heidarnezhadian *et al*. (2017)
Gypsophila paniculata	Newman *et al*. (1998)	*Tulipa hybrids*	Sexton *et al*.(2000)
Iris	van Doorn *et al.* (1995)	Waxflower	Macnish *et al*. (2000)
Narcissus pseudonarcissus	Hunter *et al*. (2004)	Chrysanthemum	Woltering and Van Doorn (1988)
Orchid (*Phalaenopsis ,Dendrobium, Epidendrum*)	Woltering and Van Doorn (1988)		
Petunia hybrida	Knee (1995)		
Carnation	Koohkan *et al.* (2014)		
Lily	Song and Peng (2004)		
Snapdragon	Asrar (2012)		

B.

Insensitive	reference	Insensitive	reference
Strelitzia reginae	Finger *et al*. (1999)	*Sandersonia aurantiaca*	Eason and De Vre (1995)

Rose	Pun & Ichimura, (2003)	*Buddleia davidii*	Redman *et al.* (2002)
Gladiolus	Costa and Finger (2016)	*Cosmos bipinnatus*	Redman *et al*. (2002)
Orchid (*Cymbidium*)	Van Doorn (2002)	*Echinacea purpurea*	Redman *et al.* (2002)

Koohkan *et al* (2014) found out that ethylene production was affected by Nano silver (NS) concentrations. The carnation cut flowers of control and the 5 mg L^{-1} NS treatment showed the maximum and minimum ethylene production respectively.



(Source: Koohkan *et al.,* 2014)

Figure 5. Ethylene production rate on various NS treatment concentration on carnation cut flower.

The ethylene production increased with enhancement in NS concentration that this increment of ethylene can possibly appeared in the response of cut flowers to stress conditions induced by NS toxicity at high concentrations. Shortening the vase life of control cut flowers was mainly due to the growth of microbes in the vase solution and the increased ethylene accumulation.

3.2 Post-harvest operations for improvement of vase life of cut flowers

3.2.1 Pre-cooling

Precooling is a treatment to remove the field heat immediately after harvest of cut flowers (Kumar *et al*., 2022). Time gap between harvest and pre-cooling should be as short as possible. It brings down the respiration rate. It can be done either by hydro-cooling or refrigeration. For

Rose, the pre-cooling temperature required is 1-3^{0}C, Chrysanthemum –0.5-4^{0}C, Carnation 1^{0}C and for Gladiolus 4^{0}C (Gupta and Dubey, 2018).

3.2.2 Storage Condition

A. Simple refrigerated storage: It is mostly used storage. The cold storage of flowers can be carried out by dry or wet (in a vase or small tubes) processes, depending on the destination of the product and length of storage.

Wet storage: In wet storage, the stems are stored with their basal portion dipping in water or preservative solution where the temperature would be 2-4°C. Wet storage holds the flower for short duration (Gupta and Dubey, 2018). Roses are usually kept for a longer storage term at 2°C with the stem base in water, as fewer dehydration symptoms are developed (da Costa *et al*., 2021).

Table 2. Optimum storage temperature for commercial cut flowers

Storage	Crop	Storage temperature	Shelf life (weeks)
Dry storage	Carnation	0 to 1^0 C	16-24
	Lily	1^0 C	6
	Anthurium	13^0 C	4
	Gladiolus	4^0 C	4
	Rose	0.5 to 2^0 C	3
Wet Storage	Lily	0-1^0 C	6
	Carnation	4^0 C	4
	Chrysanthemum	4^0 C	3
	Gerbera	4^0 C	3-4
	Rose	2 to 5^0 C	4
	Gladiolus	4^0 C	10

(Source: Kumar *et al*., 2022; Senapati *et al*., 2016)

Dry storage (Modified atmospheric storage): Sealing of flowers in plastic bags leads to reduction in O_2 and increase in CO_2 levels due to respiration of tissue (5-7% CO_2 and 1 to 2% O_2). Dry storage can be used to hold the flowers for longer duration (Gupta and Dubey, 2018). For most flowers, dry storage is performed by wrapping the flowers in bunches and placing them in cardboard boxes.

B. Controlled atmosphere (CA) storage: Here, CO_2 and O_2 level is controlled. It has a storage chamber where air is continuously circulated and is also released. Low temperature is maintained and RH is kept high (Gupta and Dubey, 2018). N_2 enrichment storages have promising result in daffodils and roses (100% N_2 & 99% N_2 + 0.5-1% O_2 respectively. Higher concentration of CO_2 at CA storage controls disease in carnation, daffodils & anthurium (Senapati *et al*., 2016). Major limitation is optimum levels of CO_2 and O_2 required for storage vary for different flowers, accumulation of ethylene occurs and hence, different flowers cannot be stored at the same time in the same chamber (Gupta and Dubey, 2018; Senapati *et al*., 2016).

C. Hypobaric storage (Low pressure storage-LPS): Storage at low atmosphere pressure along with low temperature and cooled moist air (Senapati *et al.*, 2016). i.e. 40- 60mm Hg (murcery) under continuous ventilation and high relative humidity (90-95%) in several cut flowers (Gupta and Dubey, 2018). Cut roses at 180-210 mm Hg pressure can be stored up to 3weeks with retention of 63% of the original vase life (Senapati *et al.*, 2016). Major disadvantage is high cost of installation (Gupta and Dubey, 2018).

3.2.3 Sorting & grading

During sorting, flowers which are infested with pest and diseases, damaged and defective are discarded. In addition to stem straightness, stem strength, flower size, vase life, maturity, uniformity, as well as foliage quality should all be taken into account when grading cut flowers. Mechanical grading systems must be properly planned to maximize efficiency and protect the flowers. (Reid, 2009).

3.2.4. Packaging

Package should withstand shocks, drops, vibration, compression and refrigeration during shipping and storage. The inner layer of package should also provide cushioning effect to the flowers. Some of the packaging material commonly used are cellophane paper, newspaper, fluted card board paper, polypropylene, polyethylene, craft paper and tissue paper either in the form of sleeves, cones, cups or simple wrapping over flowers. Corrugated cardboard boxes are commonly used for packaging of flowers. Package should be labeled mentioning source, crop, variety, grade and number of flowers or bunches with handling tip (Gupta and Dubey, 2018). Singh *et al*. (2007) reported that Polypropylene packing in cold storage could keep the gladiolus spikes up to 10 days. Dastagiri *et al*., (2014) observed that *Ornithogalum* spikes could be best stored up to 3 days at 4ºC in modified atmosphere packaging with cellophane. Senapati *et al.*

(2016) reported that Anthuriums were normally packaged individually. They were commonly packed in moist shredded newsprint or other shredded paper.

3.2.5 Transportation

Flowers sensitive to geotropic bending (gladiolus and snapdragon) must be transported in an upright position (Senapati *et al.*, 2016). The RH of the air during precooling and shipment of cut flowers should be maintained at the level of 95-98%. After precooling and adequate packing, cut flowers can be transported in insulated vehicles for short distances and times shorter than 20 hours without the need for refrigeration. Air transportation is the quickest, however the temperature is typically not maintained while in flight. Prior to air transportation, the flowers need to be pulsed with sodium thiosulphate (STS). Flowers that are sensitive to ethylene should be placed in boxes with ethylene scrubbers that contain KMnO4. There should be lighting inside the transporting truck because certain flower crops yellow while being transported due to a lack of light. (Kumar *et al*., 2022). However, for most species, relatively short-term storage at retail stores may be required (Horibe, 2020). In most cases, particularly in developing countries, the production areas of flowers are close to marketing centers, but even without modern postharvest handling, the final consumer still receives products of standard quality (Mahajan *et al*., 2014).

3.3 Component of preservative solution for vase life improvement

3.3.1 Water

Water is the universal solvent. water can dissolve much more substances than any other liquid found in nature. In most concentrated vase solution, water is present. Acidic water with low pH (3.0-3.5) decreases microbial growth (Van Doorn, 1995)

3.3.2 Sugar

Sucrose is the most favored preservative since it is the sugar that most cut flowers can metabolized. Besides this, other sugars like fructose, glucose, trehalose etc. are found best in some flowers. As in gladiolus, trehalose has been found to be the best preservative solution (Yamada *et al*., 2003).

Table 3. Vase life characteristics to different vase solutions of cut Red pearl rose

Treatments	Days taken for first petal spreading	Petal water content (%)	Vase life (days)
Tap water (Control)	2.1 e	28.6 j	8.3 e
Sugar (50-ppm)	4.1 c	30.6 i	8.7 e
Citric Acid (50-ppm)	1.1 f	33.0 f	8.3 e
Salicylic Acid (50-ppm)	1.1 f	33.6 e	8.3 e
Chitosan (50-ppm)	3.1 d	31.0 h	10.7 d
Silvar Thiosulphate (50-ppm)	4.1 c	52.2 c	13.7 b
Sugar + Citric Acid (50-ppm)	5.1 b	54.1 b	14.0 b
Sugar + Salicylic Acid (50-ppm)	6.1 a	65.4 a	15.7 a
Sugar + Chitosan (50-ppm)	4.1 c	31.8 g	12.0 c
Sugar + Silvar Thiosulphate (50-ppm)	5.1 b	48.8 d	14.0 b

(Source: Khan *et al*., 2015)

Khan *et al*. (2015) showed the response of cut Red pearl rose on some vase life characteristics to different vase solutions where maximum vase life was found from Sugar + Salicylic Acid (50-ppm). This also showed maximum days for first petal spreading along with maximum percentage of petal water content which shows that, this sugar & a germicide combination provides longest vase life in rose

3.3.3 Germicide or biocide

These are the chemical compound, antimicrobial chemicals that are intended to block the growth of bacteria, fungi, and some microorganisms that are present in flower vases. To prevent microbial growth, a sugar solution is always added to a biocide solution. A number of germicide solutions have been used to extend the vase life of cut flowers, including the silver compounds: STS and Silver nitrate ($AgNO_3$), chlorine compounds (sodium hypochlorite, sodium dichloroisocyanurate, and Chlorine dioxide (ClO_2), and certain other compounds, such as 8-Hydroxyquinoline sulfate (8-HQS), 8-Hydroxyquinoline citrate (8-HQC), salicylic acid

(SA), calcium, calcium nitrate, aluminum sulfate, isothiazolinone, and quaternary ammonium chloride and so on (Nguyen and Lim, 2021).

Hema *et al*., 2018 showed a specific study where biocide caused the proliferation of microbes in the vase solution in order to improve the water relations in the floral tissue which affects vase life of cut Gerbera. Increased water uptake noticed with lower concentration of sodium hypochlorite was considered to be very effective. Even at a low concentration in reducing the microbial growth thereby avoiding stem blockage and maintained continuity of water to the floral tissue.

Table 4. Different treatment containing biocide affecting vase life of cut gerbera

Treatments	Mean water uptake (g)	Mean scape bending (^{0})	Vase life (days)
Sodium hypochlortie 20 ppm	8.089	10.017	10.570
Sodium hypochlortie 40 ppm	7.483	12.591	7.897
Sodium hypochlortie 60 ppm	6.527	23.303	6.490
Calcium hypochlortie 20 ppm	6.885	25.810	8.507
Calcium hypochlortie 40 ppm	6.145	30.662	7.173
Calcium hypochlortie 60 ppm	5.663	41.944	6.270
Distilled water (control)	4.431	54.687	4.700

(Source: Hema *et al.,* 2018)

Moreover, high turgidity and mechanical strength of the flower scape due to improved water balance in the floral tissue might have led to record lowest scape bending curvature with sodium hypochlorite 20 ppm concentration in the vase solution among all. Effective control of microbial proliferation can be done and so contributed to improved quality and vase life of cut gerbera flowers.

3.3.4 Plant growth regulators

Cytokinin

Cytokinin is another hormone that has been used as a component of conservative solutions in cut flowers.

Table 5. Effect of BA on vase life of Alstroemeria cut flowers

	First experiment			Second experiment		
BA (mg/litre)	Days to full opening of primary florets	Days to 50% petal fall	Days to 50% leaf yellowing	Days to full opening of primary florets	Days to 50% petal fall	Days to 50% leaf yellowing
0 (control)	4.5bc	14.2a	18.5a	4.2c	14.3 ab	14.5ab
25	5.8a	15.2a	18.3a	6.3a	15.2a	15.7a
50	5.3ab	14.0a	18.3a	5.2b	14.2b	13.5b
75	5.3ab	12.3b	15.5b	4.8bc	13.7b	11.0c
100	4.2c	10.3c	13.5c	4.0c	12.5c	9.5c

(Source: Mutui *et al*., 2003)

Mutui *et al*. (2003) has studied about different concentration of Benzyladenine (BA) on vase life of Alstroemeria cut flowers. 25 mg/L BA followed by 50 mg/L delayed the full opening of the primary florets, delayed 50% petal fall as well as delayed 50% leaf yellowing.

Gibberellic acid- GA_3

GA_3 has been commonly used to mitigate the effects of ethylene on ornamental plants, but instead of lowering flower senescence rates, this molecule has had other impacts. (da Costa *et al*., 2021). GA_3 regulates the action of abscisic acid (ABA) in the maintenance of cell membrane and flower opening in gladiolus (Kumar *et al*., 2014; Costa *et al*., 2016). Gibberellic acid treatment produced more promising effects on the vase quality attributes at lower concentration. Saeed *et al*. (2014) found the longest time taken to open a floret was recorded with the lowest GA_3 level 25 mg L^{-1} followed by 50 mg L^{-1}. Gibberellic acid affected the percentage of opened florets in vase and the highest percentage was recorded at GA_3 25 mg L^{-1} which was statistically the same as with GA_3 50 mg L^{-1}. Again, the highest level of GA_3 200 mg L^{-1} remained statistically the same as with control treatment.

Table 6. Effect of various GA3 levels on the vase quality attributes of gladiolus cut flower

GA_3 levels mg L^{-1}	Days to open floret		Florets opened (%)		Vase life (days)	
	2010	2011	2010	2011	2010	2011
0	1.58c	1.62c	86c	87d	7.67d	7.67c
25	2.28a	2.56a	100a	100a	11.83a	11.67a
50	2.00b	2.15b	99ab	100a	10.33b	9.33b
100	1.90b	1.90b	97b	95b	9.33c	9.33b
200	1.60c	1.63c	87c	92c	8.67d	8.33bc

(Source: Saeed *et al*., 2014)

The longest vase life was also recorded with GA_3 at 25 mg L^{-1} treatment during both years. These results indicated the vase life shortening effects of GA_3 at higher concentrations.

Abscisic acid- ABA

ABA has been pointed out as a signal molecule to trigger leaf and flower senescence, as observed in carnation (Rubinstein, 2000). It has been suggested that ABA plays an important role in signal transduction events, underlying programmed cell death in day lily petals. Geng *et al*. (2015) applied 6 treatments on lily. The pulsing treatment of sucrose and 8–HQC resulted highest vase life of flowers. Among the combinations with ABA, sucrose + 8–HQC + 2 mg · L^{-1} ABA showed highest vase life of flower as well as leaves.

Table 7. Effects of different concentrations of ABA pulsing treatments on the vase life of cut lily flowers

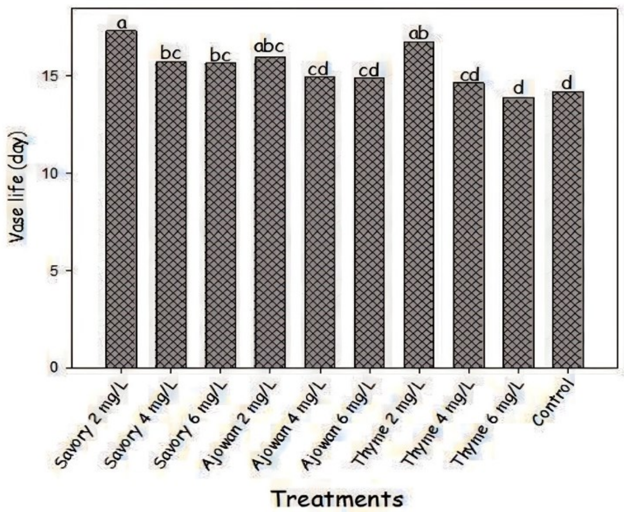
Pre treatment	Rate of flowering(%)	Vase life of flowers (days)	Vase life of leaves (days)
DI water	75	9.2±1.83	8.4±2.30
sucrose + 8–HQC	100	9.8±1.58	7.7±0.95
sucrose + 8–HQC + 2 mg · L^{-1} ABA	100	9.5±1.07	9.3±1.39
sucrose + 8–HQC + 4 mg · L^{-1} ABA	100	8.5±1.31	7.0±1.77
sucrose + 8–HQC + 10 mg · L^{-1} ABA	100	9.0±2.14	7.4±1.82
sucrose + 8–HQC + 10 mg · L^{-1} ABA	100	7.1±1.86	6.6±2.23
sucrose + 8–HQC + 50 mg · L^{-1} ABA	100	6.1±1.07	5.5±1.52

(Source: Geng *et al*., 2015)

It has been observed that, ABA is the main factor affecting senescence of cut lily flowers, and ethylene could accelerate the aging process to a certain extent. The addition of lower concentration of ABA with sucrose and 8–HQC alleviated the sucrose–induced leaf chlorosis & inhibited ethylene release.

3.3.5 Essential oils

Essential oils are natural products taken from plant materials that, due to their antibacterial, antifungal, antioxidant and anticarcinogenic properties can be used as natural additives in many crops (Teissedre and Waterhouse, 2000). Many authors have stated that using essential oils after harvest has neither negative or beneficial influence on horticulture product quality metrics (Hegazi and Gan,2009; Solagi *et al*., 2009;). The major constituents of the used essential oils are phenolic compounds (Bounatirou *et al*., 2007; Sharififar *et al*., 2007). Mirdehghan and Aghamolayi (2016) pulsed the cut flowers with calcium chloride ($CaCl_2$) and $AgNO_3$ for 1h and then transferred to preservative solution (All the holding solutions contained 2% sucrose) contained 2 mg L^{-1} of savory, ajowan, thyme and distilled water (control).



(Source: Mirdehghan and Aghamolayi, 2016)

Figure 6. Effects of different concentration of essential oils on vase life (day) of cut Gladiolus during storage at 25±2ºC.

Savory 2 mg L^{-1} exhibited as the most effective treatment for minimizing dehydration of the gladiolus cut flowers.

3.4 Post-harvest preservative treatments for vase life improvement of cut flowers

3.4.1 Conditioning treatment

Conditioning, also known as hardening, is a simple technique in which flowers are placed loosely in a large container of water so that air circulates around the stem (Senapati *et al*., 2016). Following harvest, storage, or transportation, the primary goal of conditioning is to restore the turgidity of cut flowers. (Gupta and Dubey, 2018). Conditioning is done with de-mineralized water supplemented with biocides and acidified with citric acid to pH about 4.5 to 5.5 where some wetting agents like tween 20 @ 0.01-0.10% can be used for this purpose (Senapati *et al*., 2016; Kumar *et al*., 2022). Flower stems should be submerged 2.5 cm deep in warm water at room temperature in plastic jars. Common examples include Gerbera, Carnation, Chrysanthemum, and Gladiolus (Kumar *et al*., 2022).

3.4.2 Bud opening development treatment

This is a preservative solution in which immature buds of many flowers can be made to open (Senapati *et al.,* 2016). Before the immature buds open, farmers harvest the buds at an early stage of development and keep them in a solution containing sugar, plant hormones, and germicides (Nguyen and Lim, 2021). In bud developing solution, lower concentration of sucrose are used (2-5 %) (Gupta and Dubey, 2018). Rabiza-Swider *et al*, (2020) showed that, the number of open buds in relation to their total number was considered to assess the vase life. The average longevity of cut snapdragon flowers kept in water was 10.6.

Table 8. The effects of preservative solutions on vase life of snapdragon flower

Treatments	Vase life (Days)
Water (Control)	10.6 a
Nanosilver (1 mg L^{-1} NS)	12.1 a
Nanosilver (1 mg L^{-1})+Sucrose (20 g L^{-1})	15.4 b

(Source: Rabiza-Swider *et al*., 2020)

Nanosilver alone had no effect on longevity, but with sucrose improved flower bud opening and coloration and so prolonged the vase life relative to the water by five days (45 %)

3.4.3 Pulsing treatment

Pulsing is ‘supplying a solution through transpiration stream’. Pulsing means applying higher concentrations of sucrose to the the flowers or buds for 16–20 hours. (with/without germicide). Each species or cultivar responds differently to the sucrose concentration (Nguyen and Lim, 2021). This procedure is also known as hydration, and adding a wetting chemical to water can help (Post-harvest Management of Horticultural Crop, 2011). It improves the shelf life and to promote flower opening. Pulsing is especially useful for flowers that will be stored for a long time or transported across large distances (Kumar *et al*., 2022). Gogoi *et al.* (2021) observed 6 treatments and 2 pulsing duration on Asiatic lily CV. Black Out. The highest uptake of pulsing solution (6.21 ml/stem) was in treatment comprising 10% sucrose and 50ppm BA for 24 h.

Table 9. Effect of 6 pulsing treatments and 2 pulsing duration on the vase life of Asiatic lily CV. Black Out

Treatments	Pulsing solution uptake (ml/stem)	Vase life (days)
Distilled water for 12 h	3	7.12
10% sucrose for 12 h	5	8.13
100 ppm $AgNO_3$ for 12 h	4.48	10.00
10% sucrose + 100 ppm $AgNO_3$ for 12 h	5.93	11.65
50 ppm BA for 12 h	3.63	9.00
10% sucrose + 50 ppm BA for 12 h	5.77	12.02
Distilled water for 24 h	3.30	7.38
10% sucrose for 24 h	5.33	8.52
100 ppm AgNO3 for 24h	5.38	10.19
10% sucrose + 100 ppm $AgNO_3$ for 24 h	6.20	12.83
50 ppm BA for 24 h	4.03	10.67
10% sucrose + 50 ppm BA for 24 h	6.21	13.00

(Source: Gogoi *et al*., 2021)

The higher absorption of pulsing solution may be attributed to the combined effect of sucrose and BA. Sucrose in the pulse solution provided additional respirable substrate to the cut flowers resulting in longer (13 days) vase life (Shahri *et al*., 2010). Moreover, Among the two set of pulsing duration, 24 h pulsed flowers showed better results as compared to 12 h.

3.4.4. Impregnation

The ends of stems can be impregnated with high concentration of Silver nitrate ($AgNO_3$) or nickel chloride ($NiCl_2$) or cobalt chloride ($CoCl_2$) solution for 10 minutes which protects against the blockage of water vessels in stems by microbial growth and greatly improves longevity of several flowers (Senapati *et al.,* 2016).

3.4.5 Holding solutions

Flowers are kept in a solution that contains sucrose, a germicide, an ethylene inhibitor, and a growth regulator after pulsing and storing them.

Table 10. Different holding solutions for vase life improvement of different cut flowers

Flowers	Chemicals & concentrations	References
Gerbera	Sodium hypochlorite (20 ppm), Calcium hypochlorite (20 ppm)	Hema *et al*., 2018
	DW + 8-HQS (200 or 400 mgL^{-1})	Jafarpour *et al.,*2015
Orchid (*Dendrobium*)	100 ppm 8-HQS + 2% sucrose	Jawaharlal *et al*., 2002
Snapdragon	200 ppm 8-HQS + 2% sucrose	Asrar, 2012
	400 mg L^{-1} Citric acid + 20 g L^{-1} sugar + 0.5 mlL^{-1} quaternary ammonium chloride	Ahmad and Dole, 2014
	1 mg L^{-1} NS and 20 g L^{-1} sucrose	Rabiza-Swider *et al*, 2020
Anthurium	100 ppm STS+ 3% sucrose	Muraleedharan, 2020
Lisianthus	400 mg L^{-1} Citric acid + 20 g L^{-1} sugar + 0.007 ml L^{-1} isothiazolinone	Ahmad & Dole, 2014
Rose	1.5 mM SA (continuous exposure)	Kazemi *et al.,* 2018
	50 ppm 8-HQC+1.5% sucrose	Dhiman and thakur, 2006
Chrysanthemum	2% sugar + 100ppm 8-HQS+ 100ppm Citric acid	Abou El-Ghait, 2012
	0.5 mM STS + 2% sucrose	Sharma, 1992
Carnation	5% sucrose + 50 ppm $AgNO_3$ +200 ppm 8-HQC	Chung *et al.,* 1986

It is also known as vase solution. It's basically aimed at providing nourishment to the cut flowers. The flowers can be kept in holding solution either at wholesaler, retailer or consumer level.

CHAPTER IV

CONCLUSION

After considering the above findings, it can be concluded that- increased temperature & humidity, decreased water uptake, increased transpiration, increased respiration, lower carbohydrate supply and endogenously accumulated or exogenously applied ethylene gas are the various post-harvest factors which reduces vase life and most of them the factors are inter-related.

Furthermore, post-harvest operations may include pre-cooling, storage condition (dry storage, wet storage, controlled atmospheric storage or hypobaric storage), sorting & grading, packaging & transportation. Depending upon purpose of the preserving specific cut flowers, conditioning, bud opening development solution, pulsing solution, impregnation & finally holding solution are the preservative treatments done after harvesting which contains carbohydrate in various concentration. Furthermore, most of the preservative solution possess water, sugar(respiratory substrate for providing nourishment), germicide (aimed to kill the microorganisms including bacteria), plant growth regulators (cytokinin, Gibberellic acid, abscisic acid), essential oil and combinations of them.

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