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Narendra Kumar
Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh, India

Vijay Bahadur
Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh, India

VM Prasad
Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh, India

Corresponding Author
Narendra Kumar
Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh, India

Biochemistry of post harvest management in cut flowers

Narendra Kumar, Vijay Bahadur and VM Prasad

Abstract
Flowers are beautiful and very complex commodity which deteriorates within a few days to a week only. The cut flowers having the great scope in national and international market, different methods likes use of preservatives, handling carefully and storage properly should be followed. To keep the cut flower in vase appealing to consumer for longer period, floriculture researchers have standardized various post-harvest technologies for various flowers. Prolonging the post-harvest life is essential to assure more life of flowers. For prolonging vase life, we should study about the pre-harvest, harvest and postharvest factors of flower crops that ultimately affects the flower life. There are a series of steps involved to prepare flowers for market after harvesting known as post-harvest handling. These steps include: Harvesting, Conditioning, Pre-cooling, Pulsing, Grading, Bunching, Wrapping, Packaging, Storage, Transport and Sale. All the factors that affect post-harvest life of a flower should managed properly to provide optimum condition for plant growth different biocide, holding, pulsing solution, growth regulators and different storage temperature are used to promote vase life of lowers. This review is an insight into the various storage methods such as cold storage and wet storage and numerous packaging materials (Polyethylene, Polypropylene and newspaper etc.) suggested by various researchers for particular cut flower. This will gives the base for the further post-harvest studies of cut flowers.

Keywords: Wet storage, dry storage, cut flowers, packaging, and transport

Introduction
Flowers are one of the most beautiful natural forms out there. Flowers are a part of the lifecycle of fruit and a multitude of plants bear them. Some flowers, because of their visual appeal flowers are considered very high-value commodities and are traded locally and globally across the world every day. As important as it is to ensure that the right quality flowers are grown in abundance in a farmer's land, it is equally important to ensure that they are handled the way they are supposed to be.

This post is about managing cut flowers like Rose, Gerbera, Chrysanthemum, Orchids etc., after they are harvested to ensure maximum post-harvest life of flowers. While it is important to manage each flower differently as they may have different needs, the basic principle behind managing their shelf life pretty much remains the same for all of them. For the purposes of this post, it must be noted that the life of a flower after it is harvested simply means the timespan until which the flowers overall strength, texture, color and visual appeal is maintained.

Cut flowers are highly perishable commodities and vulnerable to various postharvest losses. Market losses in the cut flower owing to inefficient postharvest storage and packaging are estimated around 20-40% (Jawaharlal *et al*., 2006) [27]. Storage of flowers is crucial to facilitate the adjustment of flowers to market demand, enables the accumulation of large quantities of flowers for distant shipment and extends sale period for high value flowers (Goszczynska and Rudnicki, 1988) [24]. Solo storage of flower is sometime deleterious, so proper packaging and pulsing become obligatory.

The management practice followed decides the quality of the crops over time after harvest, right up-till final consumption. With the primary goal being preserving the quality of produce and avoiding losses, a good post-harvest management practice entails avoiding moisture losses, preserving nutrient value, prevent undesirable chemical changes and avoiding physical damage of the produce thereby preserving the aesthetic aspects that the end consumers pay for and care about.

The day-to-day modern age is enjoying every moment and every memorable day with flowers. Be it an inaugural function or any important day e.g., teacher's day, Mother's Day, valentine's day, friendship day or a national day, all the occasions include a utilization of flowers,

particularly cut flowers.
Besides this all the feelings are now expressed with the presentation of flowers. The expression of love is done by presenting rose, expression of women's love by presenting red rose or carnation, similarly iris for message, snapdragon for presumption, daffodil for regard, marigold for sorrow, lotus for purity, and lily for luxury.
This indicates that flowers have a prime position in current day to day life. Keeping in view the importance of cut flowers and its fast-growing rate due to increasing demand it diverts attention towards the various aspects of cut flowers particularly how to extend vase life.
Earlier flowers were judged on the basis of physical parameters like colour, size of bloom, stem length of flower, quality of leaves and overall appearance but, besides these factors longevity after harvest is the most important factor considered.
Post-harvest plays the most important role as the aesthetic value pays the price of the produce. In any marketing system, quality assurance of the product plays the most important role so as to earn profit and this is highly implemented on highly perishables like flowers. Quality of a flower to a consumer is very important as it is associated with the status and dignity of a consumer.

Factors affecting post-harvest life of spike during storage
Temperature
Temperature influences the metabolic activities of plants. Low temperature during storage or shipment period reduces the entire metabolism in the tissues, slows down the respiration, transpiration, ethylene production and action and retards the multiplication of bacteria and fungi.

Humidity
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).

Water
Water is essential to maintain the turgidity of spikes of cut flower. Slightly acidic water checks the growth of harmful bacteria and fungi.

Air exchange
The associated biochemical and physiological changes associated with the post-harvest quality of flowers are largely affected by O_2 and CO_2 levels. So altering the levels of these two can enhance the vase life by large extent.

Microbial activity
Fungi and bacteria cause rotting and thereby deteriorate flower quality. Effective management of these pathogens can extends shelf life of cut flower to a large extent. Celikel and Reid, 2002 [17] confirmed that vascular plugging in cut flowers caused by bacterial colonies development is the major reason for lesser vase life.

Ethylene
Ethylene is one of important plant growth regulator. It plays an important role in hastening the senescence of the flower. There are a number of inhibitors of ethylene action are used such as, Silver Thiosulfate, 2,5- Norbornadiene and 1-Methylcyclopropene (1-MCP). Exogenous ethylene in a large number of cut flower can be controlled by using the 1-MCP (Celikel and Reid, 2002) [17]. Hence, throughout entire storage period it is necessary to maintain uniform temperature, relative humidity, air circulation and sanitation of storage room.

Post-harvest handling of the crop is the most important aspect in getting the right value for the crop. A typical post-harvest management practice of flowers comprises of the following stages
Pre-cooling
It is required to bring down the temperature of the flowers down to a much lower temperature (around 10 ^{0}C but not below the recommended storage temperature) as soon as the harvesting is done. Buckets containing flower stems dipped in water or water solution of preservatives should be kept in a pre-cooling chamber.
One may prefer doing cleaning, de-leafing, and bunching after harvest and then pre-cool but it should be done as quickly as possible. Refer the points that follow to know more about them. This operation should be finished within six hours or less.
Pre-cooling removes field heat quickly, arresting the metabolism/respiration and extends the life of the flowers.

Cleaning and De-leafing
The leaves from the lower portion of the stem are removed. All infected leaves are also removed. Precautions should be taken to prevent crop injury during these processes.

Grading, Sorting and Bunching
The grading of flowers should be done according to the stem length, bud size, stem thickness and opening of flowers. Depending on the requirement of a buyer, appropriate thumb rules should be applied for these processes. The requirement of grading could be different in Indian market than what it is in say, Netherlands. Bent neck, thorn damage flowers, disease and pest affected and thick stem should be rejected.

Storage Methods
Storage of flowers can be of following types.
1. Cold storage
   a. Wet storage
   b. Dry Storage
2. Controlled atmosphere storage (CAS)
3. Low pressure storage (LPS)
4. Modified atmosphere storage (MAS)

Cold Storage
It facilitates adjustment of flower stock to the market demand. It is most economical and widely used method of flower storage.

Table 1: Pre-cooling Temperature of flower storage

Sr. No.	Crop	Pre-cooling Temperature
1.	Anthurium	13 ^{0}C
2.	Alstroemeria	4.0 ^{0}C
3.	Chrysanthemum, Cymbidum, Paphiopedilum	0.5- 4 ^{0}C
4.	Dendrobium	5- 7 ^{0}C
5.	Gladiolus	4-5.0 ^{0}C
6.	Rose	1-2 ^{0}C
7.	Carnation	0.5- 1.0 ^{0}C
8.	Gerbera	4.0 ^{0}C

Source: Janick, 2011

Wet storage
In this method spikes are dipped in water or some preservative solution during storage. The cut flowers are kept in water or preservatives solution at 3-4 ^{0}C for a short time. Carnation, Gerbera, Lily & Snapdragon can be best stored under this method (Singh *et al*., 2007) [38].

Table 2: Preservative temperature of during cut flowers storage

Sr. No.	Flowers	Storage Temperature	Maximum Storage period
1.	Rose	2 ^{0}C	10 Days
		4 ^{0}C	4 Days
2.	Gladiolus	0.5-1.6 ^{0}C	10 Days
3.	Gerbera	4 ^{0}C	3-4 Weeks
4.	Lilium	0-2 ^{0}C	3 Weeks
5.	Tuberose	4-5 ^{0}C	4 Days
6.	Orchids	4 ^{0}C	2-3 Weeks
7.	Chrysanthamum	0.5-2 ^{0}C	12-15 Days

Source: Janick, 2011

Dry storage
In this method fresh flowers are wrapped in plastic packaging or any other suitable packaging material to prevent the loss of moisture after harvesting & grading. Prior to storage flowers are treated with fungicide and pulsed with floral preservatives (Singh *et al*., 2007) [38].

Controlled atmosphere storage (CAS)
This is a storage method with lower level of $O_2$with a higher level of CO_2 (up to 4%) in gas cool chambers with cooling system. This led to reduction in the physiological processes consisting of respiration and production of ethylene. (Singh *et al*., 2009) [34].

Modified atmosphere storage
Modified atmosphere storage (MAS) is less cumbersome and more economical than the controlled atmosphere and low pressure storage. The storage response of flowers depends upon the maintenance of positive water balance in the stem and ultimate concentration of CO_2 and O_2inside the packages during storage (Singh *et al*., 2009) [34]. Considerable variations occur among flower species in their response to modified atmosphere conditions during storage (Goszczynska and Rudnicki, 1988) [24].

Packaging
The flower buds should be wrapped with white or brown paper wrappers. The size of the wrappers depends upon the bud size and number of flowers per bunch. Using rubber bands of 2 into 4 in sizes below the bud and at the bottom of the stem help in minimizing transport injury and are recommended.

Packaging material
A number of packaging material are used while placing flower spike for storage most frequently used are Polypropylene (PP), Low Density Polyethylene (LDPE), PO (Polyolefin), Cellophane, Butter paper, Newspaper, Banana leaves etc.

Qualities of Packaging Material
The requirement of attributes of packaging material with respect to floral product are flower quality maintenance, water loss reduction, protection from physical injury, convenient to use, traceability and make the floral product easy to handle in transportation. The qualities of packaging material are strong enough, resistant to moisture, low cost or reusable, and finally friendly with packing line machinery. Selection of a suitable packaging material to create an optimal passive modification of CO_2 and O_2 levels is of utmost importance for storage of cut flowers (Patil and Singh, 2009) [35].

Grading
During sorting, flowers damaged, infested with pest and diseases and defective are discarded. Good flowers are graded according to the bud size and stem length. Uniform buds with stem length of a particular grade range are bunched in 10, 15 or 20 number. Grading is normally done on the basis of flower quality judged by bud or bloom regularity, stem length and straightness. The grades prevailing in roses and gladioli in international trade are given below.
The flowers which are uniform in colour, stem length and development are grouped together. Internationally recognized grades are as follows.

Gladiolus
Four grades are used on the basis of overall quality, length of spike and number of florets per spike (Staby *et al.,* 1978). While grading care should be taken to discard the bruised, broken, diseased and insect damaged flowers. Same grade flowers are bunched together and wrapped with cellophane paper to improve the display value.
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. Singh *et al.,* in 2007 [38] reported that Polypropylene packing in cold storage can keep the gladiolus spikes upto 10 days. Dastagiri *et al.,* (2014) observed that *Ornithogalum* spikes can be best stored up to 3 days at 4 ºC in modified atmosphere packaging with cellophane.

Chrysanthemum
Most of the Standard chrysanthemums are placed in sleeves (50 gauges) and packed in display boxes measuring 91 x 43 x 15cm. They are placed in the boxes according to the grades. For bulk packing of the spray chrysanthemums, 10, 15 or 20 stems are placed in sleeves& packed in box measuring 80 x 50 x 23cm. It is wrapped in plastic and stored for 6-8 week at 0.5 ^{0}C. Recommended temperature for truck shipment is 2-4 ^{0}C. Azordin (600 ppm) treatment for half hour protect from pest and diseases. Pillow of corrugated paper under neck of large bloom prevents mechanical damage. Pulsing with different solution shows better keeping quality yet sucrose 2% + AgNO3 (25 ppm) + citric acid (75 ppm) and sucrose (2%) + 8 HQC (500 ppm) are recommended best holding solution for bud opening and increased vase life of chrysanthemum. Slight acidic and biocidal nature of 8-HQC increase its efficiency as floral preservative (Gupta *et al.,* 2006) [25].

Gladiolus
Storage of gladiolus below 1.6 ^{0}C proven detrimental and it also fail to open when taken out of long term storage. Though, 6-9 days storage is satisfactory, yet can be stored for 30 days

under low pressure storage technology. Spikes when harvested for local market are submerged in water. Perforated card board or wooden box of 120 X 60 X 30 cm size is used for packing. It is recommended to put immediately on water after reaching distant market. Refrigerated van can keep quality for long distant shipment. Nelofar and Paul, (2008) [32]. reported that with increasing storage duration the quality and vase life of gladiolus decrease significantly. The spikes of gladiolus dry-stored in polyethylene sleeves showed considerable decline in post-storage vase life and opening of florets, with an increase in storage duration. The post-storage vase life, however, varied in different cultivars (Singh *et al*., 2006). Polypropylene sheet reported to maintain high $CO_2$and low O_2 level. Spikes harvested when 1-2 bud start showing colourexhibit less vase life then those when 4-5 start showing colour for 7 and 14 days but more for 21 days storage. Spikes of later could be dry stored with PP 100 and PP 200 for 7 days with vase life 7.67 and 6.67 days respectively (Singh *et al*., 2008) [21]. The spikes wrapped in cellophane and stored at 4 °C for 48 hr exhibited better vase life than those wrapped in newspaper, Reason being decrease in water loss and a buildup of high relative humidity inside the cellophane packages Beura and Singh, (2003) [14]. Floret failed to open after 21 and 28 days of storage, floret size decline with increase in storage duration and was more in spikes stored in PP100 and PP 200and maximum number of floret opening also decreased with storage duration (Singh *et al*., 2008) [21]. The effect of wet packing of gladiolus on physiological loss in weight (g), vase life and floret size of gladiolus cv. 'Sylvia' and reported that the low temperature with a very and high relative humidity is favourable for decreasing the post-harvest losses in most of the cut flowers. The wet storage with sucrose at 3% for 48 hours was effective when wrapped with polyethylene at low temperature (10 °C) storage. However, the wet storage with sucrose 4% for 48 hours in storage as well at room temperature maintains the turgidity of flowers with the higher per cent floret display and vase life and also reduce the extra cost input for maintain the low temperature (Munsi *et al*., 2011) [19]

Narcissus

Vase life of Jonquil and Paper white cultivars of Narcissus decreased with increasing range of storage temperature. Dry storage of narcissus was found better at early stage but wet storage of narcissus was found better later. Respiration increase exponentially over temperature range 0-12.5 ^{0}C and vase life decrease exponentially with increasing storage temperature (Cevallos and Reid, 2000) [18].

Carnation

Carnation is very sensitive to post harvest treatments and longevity can be doubled if handled carefully. It can be stored normally for 2 weeks but under low pressure condition upto90 days. Stage of harvesting has great impact on ability to storage duration without deterioration of quality. Light bud stage can be stored for 20-24 week at 0-1.1 ^{0}C where as partial open for 6-10weeks and fully open for 2-3 week. Flowers are packed in bunches and sleeved in plastic sheets or newspaper as per requirement of customer. Generally cardboard boxes having 122cm X 50cm X 30cm dimension are used. 10ppm 8-HQC + 2% sucrose was found best for improving longevity and quality, increased flower diameter, solution uptake and reduced fresh weight losses. Aluminium sulphate in vase solution is responsible for increasing vase life along with sucrose as it is known to check microbial growth. Combination of biocide and ethylene inhibitor alone or with sucrose tends to increase vase life, and improve flower quality (Bhatia *et al.*, 2002) [15].

Gerbera

Use of germicide like 8-HQS reduce the population of microbes, and sucrose alone increase microbe population. Maximum vase life win gerbera as recorded in sucrose 3%+8-HQS 200 ppm or Sucrose 3% + Aluminium Sulphate 200 ppm along with better freshness, colour and least bent neck (Chakrabarty *et al*., 2011) [19].

Daisy (*Aster amellus)*

Daisy flowers showed maximum solution uptake, fresh weight and vase life in 0.4% 8-HQS (116.7%) and minimum fresh weight was found in distilled water. Other treatment used was Aluminium Sulphate (0.2 and 0.4%), 8-HQS (0.2%), sucrose (1 & 2 %), citric acid (100ppm) silver nitrate (0.003%) and distilled water (Patil *et al.*, 2009) [35].

Effect of different storage and pulsing

In all the three species of Iris, the enhanced vase life was recorded in scapes kept at 5°C under dry or wet storage as compared to the corresponding scapes kept at higher temperatures (10 °C and room temperature). The postharvest performance of scapes was found to be better in scapes transferred to sucrose as compared to the corresponding scapes transferred to distilled water (Ahmad *et al.*, 2013) [3].

Table 3: Different Storage temperature and pulsing rate of flower corps

Sr. No.	Crop	Pulsing	Storage temperature	Storage life
1.	Rose	2-5% sucrose	0.5-2 ^{0}C	7-10 Days
2.	Chrysanthamum	2-5% sucrose	0.5-2 ^{0}C	12-15 Days
3.	Gladiolus	20% sucrose	4.0-5 ^{0}C	7-15 Days
4.	Gerbera	20% sucrose	4.0 ^{0}C	4 Weeks
5.	Orchid	----------	5-7 ^{0}C	----------
6.	Anthurium	----------	13 ^{0}C	----------
7.	Crossandra	----------	15-20 ^{0}C	----------
8.	Tuberose	20% sucrose	7-10 ^{0}C	10-12 Days

Use of growth regulators

Post-harvest life of flowers can be controlled by growth regulators. Water relation changes associated with flower senescence are also influenced by growth regulators. Auxin does not play much role in improving vase life.

Gibberellin helps in Delaying senescence. It promotes the opening of immature buds in gladiolus. Outer bracts of Gladiolus regulate production of alpha-amylase Saeed *et al.*, 2013 reported that the application of GA3 at 25–50 mgl-1 renders the highest results for improving the vase life and quality of gladiolus cut flowers.

Cytokinins play important role in delaying senescence. Level of cytokinins decreases with ageing. BAP in holding solution delay senescence of Tuberose. Dip treatment of BA increases vase life of *Anthurium*. Mature coconut water is considered as a rich source of sugar, electrolytes (Jayalekshmi *et al.*, 1986) and growth regulators such as auxin, gibberellins and cytokinin (Mamaril *et al.*, 1986) Agampodi and Jayawardena, 2007 [38] observed that Anthurium cut flower variety wild pink when treated with 50 % Coconut water with 0.23 % NaOCl shows longest vase life (21 days). Coconut water has been successfully used to increase the post-harvest life of Gerbera

(Nair *et al.*, 2000) [33]
Ethylene a hydrocarbon gas, and commonly known as a ripening hormone induces senescence in many flowers. 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 roses. Celikel *et al.*, 2002 [17] studied the effect of 1-MCP and promalin on oriental lily and observed that 1- MCP play an important role in preventing post-harvest deterioration of buds and flowers caused by ethylene.

Transportation
The size of the packing box varies with the stem length, number of stem and distance of the destination where the flowers are to be sold. A 3 to 5 ply corrugated paper box or a corrugated fibreboard box should be used for transportation. Bunches should be placed in a row along the length of box with bunches facing in opposite direction. The second layer is placed opposite to the first layer. The bunches should be packed tightly enough for them to not move undesirably during transport. The boxes should be secured with straps for proper packaging.
Loading should be done in shaded conditions and must be done as quickly as possible. Flowers should never be transferred from the cold room to direct sunlight during the process. It is recommended to maintain the storage temperature during transport in a reefer container. Though the flowers can also be transported without reefer containers, it must be noted that flowers have a limited vase life, generally 1–3 days before which they should be consumed after being taken out of the cold room.

Conclusion
Storage, packaging and transportation are indispensable for advancing vase life and sustaining quality of cut flower. Significant improvement among various cut flower species have been reported by manipulating stage of harvesting, supplying preservative and alternative food material, proper packaging, and storage conditions.

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