# POST HARVEST PHYSIOLOGY AND TECHNOLOGY OF CUT FLOWERS

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**Abstract:** Precise information about the best postharvest handling techniques for different cut flower species is difficult to obtain. Vase life or longevity of a cut flower is determined on the basis of attributes like diameter and length of florets, opening of flowers, changes in fresh weight, diameter and length of stem or pedicel, senescence pattern, colour of petals, total longevity and foliage burning. Vase life - of cut flowers depends upon the rate of transpiration through open stomata of leaves. Increase in respiration and hydrolysis of cell components are the two major metabolic and biochemical changes that occur in senescing petals. Colour fading and discoloration is an important factor in determining the keeping quality of cut flowers. Two major pigments contributing to colour of flowers are carotenoids and anthocyanins. In senescing plant tissues, phenolic compounds have the role of scavenging superoxide, phenoxyl and hydroxyl radicals. Flower maturity, temperature, food supply, light, water supply, bacterial plugging, physiological plugging, ethylene, diseases, mechanical damage, air embolism, growth tropisms are the major factors affecting post harvest quality of cut flowers.

**Keywords:** biocides, cut flower, hydrolysis, respiration, senescence.

**Introduction:** Precise information about the best postharvest handling techniques for different cut flower species is difficult to obtain. Although some of the popular growers and florists magazines have recently published issues emphasizing "flower care", much of the information in them is often sketchy and inaccurate. This article quotes the useful experience of industry leaders, but also propagates a number of myths concerning the handling of some flowers. Concise, practical guidelines for those handling cut flowers from the time of harvest to final sale are needed to ensure an industry-wide standard of excellence. Much of the research on the handling of cut flowers carried out in recent years has not yet been put into practice in the field. This chapter is intended for growers, shippers and retailers of cut flowers and it reports the best methods presently known for improving the postharvest quality of their products.

**Factors affecting postharvest quality of cut flowers:**

**Temperature:** Respiration of cut flowers, an integral part of growth and ageing, generates heat as a by-product. Furthermore, as the ambient temperature rises, the respiration rate increases. For example, a flower held at 85°F (29°C) is likely to respire up to 45 times as fast as a flower held at 35°F (2°C). The rate of ageing can be dramatically reduced by cooling the flowers. Rapid cooling and proper refrigeration are thus essential for maintaining quality and satisfactory vase life of cut flowers. The optimum temperature for storage of most of the common cut flowers is near the freezing point (32°F/0°C). Some tropical crops such as anthurium, bird-of-paradise, some orchids and ginger are injured, at temperatures below 50°F (10°C).

**Light**: The presence or absence of light during storage is generally not a concern, except in cases where yellowing of foliage is a problem. The leaves of certain cultivars of chrysanthemum, protea, daisy and other crops turn yellow if stored in darkness at warm temperatures. The blackening of leaves of cut flowers of protea can be prevented by maintaining the flowers in high light.

**Air embolism***:* Air embolism occurs when small bubbles of air (emboli) are drawn into the stem at the time of cutting. These bubbles cannot move far up the stem, so the upward movement of solution to the flower is restricted. Emboli can be removed by either re-cutting the stems under water (removing about 1 inch), ensuring that the solution, is acid (pH 3 or 4), or by placing the stems in a vase solution heated to 41°C. High relative humidity has been shown to affect neither stem hydraulic conductivity nor its recovery after artificial induction of air emboli at the cut surface [8].

**Water supply:** Cut flowers especially those with leafy stems, have a large surface area, so they lose water and wilt very rapidly. They should be stored at relative humidity above 95% to minimize water loss, particularly during long-term storage. Water loss is dramatically reduced at low temperatures, another reason for prompt and efficient cooling of cut flowers. Even after flowers have lost considerable water (for example during transportation or storage) they can be fully rehydrated using proper techniques. Cut flowers will absorb solutions without difficulty provided there is no obstruction to water flow in the stems.

**Water quality:** Hard water frequently contains minerals that make the water alkaline. Alkaline water, which does not move readily through cut-flower stems, can substantially reduce vase life. This problem can be overcome either by removing minerals from the water (by using a deionizer) or by making the water into acid. Commercial flower preservatives may not contain enough acid to acidify

some very alkaline waters. In that case, more acid should be added to the water. Certain ions found in tap water are toxic to some cut flowers. Sodium (Na), present in high concentrations is soft water is, for example, toxic to carnations and roses. Fluoride (F) is very toxic to gerbera, gladiolus and fresia; fluoridated drinking water contains enough F (about 1 ppm) to damage these cut flowers.

**Bacterial plugging:** As stated before, the quality and vase life of flowers can be improved by supplying more food (as sugar) after harvest. Sugar can, however, also act as food for the growth of detrimental fungi and bacteria in the water and this growth can be further enhanced by organic materials that leak out of the cut stem. Substances produced by the bacteria and the bacteria themselves, can plug the water-conducting system. For this reason, it is important that buckets should be cleaned and disinfected regularly and that flower-holding solutions should contain germicides to prevent the growth of microorganisms. An acidic solution can inhibit the bacterial growth.

**Physiological plugging:** When a plant is cut or injured the cells at the cut surface may respond to the damage by closing off the wound. In nature, this response helps in preventing infection of the plant through injured surfaces. Physiological plugging in cut stems seems to result from deposition of pectic materials in the xylem elements. Obviously, such deposits drastically reduce water flow and lead to early wilting.

**Acidity:** Flowers prefer acidity (pH) of 3.2-3.5. If the solution is not in this range, add more acid to the preservative formulation. Typical hard waters can be brought to the desirable pH by the addition of 300-500 ppm (parts per million) of citric acid. Aluminum sulfate and 8-HQC (common constituents of preservative solutions) also increase the acidity of the preservative solution.

**Ethylene effect:** Certain flowers, especially carnations and some rose cultivars, die rapidly if exposed to minute concentrations of ethylene gas. A number of cut flowers produce ethylene as they age. In carnations and sweet peas, this ethylene is involved in the death of the flower. In other flowers, such as snapdragon and delphinium, ethylene causes flower abscission or shattering. Ethylene gas is produced in large quantities by some ripening fruits and it is also produced in high concentrations during combustion of organic materials (eg: gasoline, firewood, tobacco). Levels of ethylene above one hundred parts in one billion parts of air (100 ppb) in the vicinity of most cut flowers can cause damage and therefore should be avoided. Storage and handling areas should be designed not only to minimize contamination of the atmosphere with ethylene but with adequate ventilation to remove any ethylene that does occur. Treatment with the anionic thiosulfate complex of silver (STS) reduces the effect of ethylene (exogenous or endogenous) on some flowers. Finally, refrigerated storage is beneficial in that ethylene production and ethylene sensitivity of the product are reduced greatly when temperatures are low.

**Growth tropisms:** Certain responses of cut flowers to environmental stimuli (tropisms) can result in quality loss. Most important are geotropism (bending away from gravity) and phototropism (bending towards light). Geotropism often reduces quality in spike-flower crops like gladiolus and snapdragon, because the flowers and spike bend upward when stored horizontally. These flowers should be handled upright whenever possible.

**Post Harvest Physiology of Cut Flowers:** A cut flower is an intricate organ composed of different morphological units including sepals, petals, androecium, gynoecium, even stem and leaves, all of which senescence at different rates. Vase life or longevity of a cut flower is determined on the basis of attributes like diameter and length of florets, opening of flowers, changes in fresh weight, diameter and length of stem or pedicel, senescence pattern, colour of petals, total longevity and foliage burning [18]. In general, cut flowers complete their life cycle in two distinct phases (I) bud swelling to bud opening, and (II) maturation, senescence and wilting. Flower bud development to swelling involves growth or change in orientation of petals or subtending tissues and may also require abscission of protective structure. The poor opening of cut 'Madelon' roses is due lo relatively low levels of reserve carbohydrates in the corolla [31]. Acid invertase activity of perianth tissue is correlated with the specific rate of elongation [17]. The outer bracts of gladiolus regulate the production of amylase and petal growth by red/far-red control [12]. The enzyme is transported from the petal epidermis lo the ground parenchyma where it hydrolyses the extensive starch reserves [13] whereas intact stamens promote the growth of the isolated corollas through the production of gibberellins [14]. Visible petal growth requires two quantitative processes [31]. First, the cell wall must be able to expand and, second, water must enter the cell. In roses, bud development is associated with an increase of fructose concentration and decrease or no change of other carbohydrate concentrations, [23]. The cells in abscising petals may show loss of water prior to abscission and hence show a small increase in cell leakiness [2].

**Physiological Changes in Cut Flowers:** For many years research has mainly focused on maximizing vase life during the postharvest period. However, the physiological and anatomical characteristics that ultimately determine the vase life potential of the cut

flower are formed during the preharvest period [29], [7]. At water stress conditions, some plants are able to increase the solute content per cell through osmotic adjustment [15]. Reference [19] shows that dehydration causes a decrease in rose water potential from about 1.8 bars at saturation to 13 bars at dry weight loss. Cold storage at 4°C increased water potential of 'Folklore" cut roses and six days storage recorded highest water potential; however, three days stored at $4^{o}$C only gave maximum vase life. In most of vegetative tissues, the overall synthesis of ethylene is conversion of SAM (S-adenosylmethionine) to ACC (1-Aminocyclopropmie-1-carboxylic acid). Changes in gene expression during petal senescence have been studied through transcriptomics of a number of model flowers (eg. Petunia, Arabidopsis) and cut flower species (eg. Alstroemeria, Dianthus, Iris, Sandersonia) [10]. Long lasting flowers contain higher endogenous ethylene concentration than the short life flowers. The short life (lowers have a high concentration of ABA at full bloom and a cvtokinin/ABA ratio compared with in the long life flowers [34]. Rate of respiration has a bearing on the length of rose cut flowers. In a growth chamber experiment, [21] studied the stomatal responsiveness of roses grown at high RH and either using high pressure sodium lamps or light emitting diodes (red and blue) having 5 and 20% blue light, respectively.

**Ultra structural and Biophysical Changes during Petal Senescence:** Petal senescence is commonly accompanied by biochemical, biophysical and morphological deterioration. In membranes, decreasing lipid fludity is one sign of deterioration [4]. Several authors have reported that senescence is accompanied by a dramatic increase in the leakage of several molecules such as amino acids, sugars, $K^{+}$ ions and total electrolytes [1]. The vase life of many flowers is limited by an occlusion in the stem due to outflow of latex, gum, mucilage, resin and bacterial growth [32]. According to the reference [25] reported that diacylglycerol (DAG) may have a regulatory role in flower senescence in relation to protein phospohorylation on the action ethylene and synthesis. In pre-senescent petals of carnations, limited vacuolar and cytoplasmic vesiculation is observed along with dilation of the outer mitochondrial membrane.

**Biochemical Changes during Senescence:** Increase in respiration and hydrolysis of cell components are the two major metabolic and biochemical changes that occur in senescing petals. The inner petals of cut roses exhibit a consistently higher respiratory rate than the outer petals regardless of whether the flower is kept in water or preservative solution or on the plant itself [22]. The continuous supply of sucrose or glucose to the inflorescence of cut dahlias resulted in the accumulation of reducing sugars and sucrose in the flowers. All organs of cut carnations are capable of transforming to sucrose when treated with glucose. Sucrose synthetase activity was highest in leaves, stems, sepals and ovary. Sucrose hydrolysis occurred almost exclusively in petals Sucrose uptake by gladiolus spikes from the vase solution replenished intracellular and respirable carbohydrates, allowing a sustained high respiration rate and a prolonged vase life in 'Raktagandha' cut roses, total starch content in petals had a tendency to increase on the third day in the vase over that of first day and thereafter decreased at senescence. In general, higher starch content, TSS content, RS content and total phenols content; and lower TFAA content in petals were associated with longer vase life.

Reference [30] reported that in carnation and rose flowers, the respiration rate increases on the first day after harvest followed by a decline to a minimum on the third and fourth days, and it may be attributed to extensive protein break down and decomposition of amides and amino acids. Kinetin treatments tended to maintain old leaf proteins comparable to fresh leaf proteins are significant in the process of senescence and the chemical control of protein in-vitro might help to maintain freshness of flowers. Protease activity increases in petals of cut 'Sonia' roses with a decrease in ovaries, but does not differ between ethylene treated and control flowers. There was not correlation between individual or total free amino-acids and protease activity in the corollas of ethylene treated, cold stored and control flowers.

In general, the lower activity of peroxidase (POD) and catalase (CAT) and higher activity of polyphenoloxidase (PPO) at senescence of 'Raktagandha' cut roses was associated with longer vase life. The activity of all the three enzymes studied showed an increase after pulsing, which decreased after storage and further decreased at senescence. Generally, POD and CAT activity was higher in petals as compared to leaves, whereas PPO activity was higher in leaves than in petals [30].

In gerbera cut flowers, the content of phenols differs with cultivars [6]. Fructose, glucose and sucrose were the main carbohydrates in petals, whereas the concentrations of other soluble carbohydrates were lower at harvest in roses [16]. Treatment with methyl glucoside and xylose promotes bud opening through metabolism. Superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD) activities decrease at first and then increase, the activity of SOD peaking at the full bloom stage, while activities of CAT and POD peak when the flower stalks begin to bend. Gibberellic acid at 25 mg $L^{-1}$ caused the longest time taken to open the floret and increased the floret opening, vase life duration and fresh weight. The highest antioxidative activities of superoxide dismutase and free radicals scavenging were also

recorded with GA3 at 25 mg $L^{-1}$. The highest peroxidase, catalase activity and the lowest membrane leakage were recorded with GA3 at 50 mg $L^{-1}$ [28]. In tulips, refer simply to the reference number, as in [24] observed that soluble protein contents decline significantly in the first three days after harvest and petal wilting is associated with a rapid increase in *de nova* synthesis of lipoxygenase (LOX). In carnations, senescence of flower petals is regulated by the phytohormone ethylene and is associated with considerable catabolic activity. The activities of acid and alkaline pyrophosphatases increase with ageing in roses, chrysanthemum and carnations.

**Pigmental Changes:** Colour fading and discoloration is an important factor in determining the keeping quality of cut flowers. Two major pigments contributing to colour of flowers are carotenoids and anthocyanins. Experimental evidence indicates that green chloropiasts are converted into large chromoplasts during various stages of senescence [3]. An increase in oxygenated carotenoids is found in roses with age; where as a decrease in the content of carotenoid is found in senescing chrysanthemum. Changes in pigmentation due to anthocyanin have a differential trend in senescing flowers. Co-Pigmentation with flavonoids and other related compounds determine the intensity of colour in most of the flowers. The bluing of red flowers with ageing and the increase in pH may be ascribed to the breakdown of protein and the release of free ammonia. A decrease in pH in some flowers may be due to an increase in the content of organic acids such as aspartic, maleic and tartaric acids.

In some other flowers, senescence is characterised by browning and blackening of petals caused by oxidation of flavones, leucoanthocyanins and other phenols and the accumulation of tannins. The petal blackening of 'Baccara' roses has been related to an increase in anthocyanin content at low temperature and to the accumulation of oxidation products of polyphenols. An increase in the loss of anthocyanin when cut roses are treated with a preservative solution containing 2 per cent sucrose + 250 ppm 8-HQC + 500 ppm citric acid and 25 ppm silver nitrate. In Iris petals, tepals show an increase in ion leakage and anthocyanins, prior to the visible symptoms of senescence [9].

**Changes in Phenolic Compounds:**Phenols are known to act as antioxidants in plant systems and play an active role in plant resistance and defence against microbial infections. In senescing plant tissues, they have the role of scavenging superoxide, petoxyl and hydroxyl radicals. In gerbera cut flowers, the content of phenols differed with cultivar [6].

**Changes in Vascular Morphology:**In cut roses, increase in resistance to water flow through stem segments predominantly in the lower most one centimetre of the stems was noticed [11]. Scanning Electron Microscope (SEM) observations of cut roses have revealed that the cut surface of the stems act as a coarse threaded filter. Only a fraction of the microbial cells enters through the vascular system from the vase water and the rest remains attached to the submerged cut surface of the stem, thus blocking the uptake of water. In a SEM analysis of cut "Sonia" roses, Put and found degradation of wall structures, injury of the vessel pit structures and mucoid materials in the vessel system after the vase life. Reference [31] detected amorphus plugs made of carbohydrates, lipid and protein-like materials. As per the reference number [32] found globular bodies covering the vessel cells completely with a white granular layer in rose cultivars with comparatively shorter vase life during senescence. Studies conducted on different cultivars of roses revealed no evidence of fungi, bacteria or any other materials in the freshly cut surfaces of rose stems examined through SPM. In contrast to the harvest stage, the cultivars 'Dr. B. P. Pal" and 'Priyadarshini expressed blockage symptoms in the vascular system on the third day of vase life except for the cultivar 'Eiffel Tower' with no blockage in the vascular system In the cv. 'Arjun', the cut stem of rose held in tap water for three days showed damage of secondary tissues partly, but with no blockage of xylem vessels. In an investigation on "Raktagandha" cut roses, a freshly cut stem surface showed a clear vascular system. A slight thickening of xylem vessel walls developed on the third day in vase and, at senescence, there was heavier thickening of xylem vessel walls along with severe damage of secondary tissues. When pulsed with DMSO (2 per cent) for 15 minutes, the vascular system was comparable to that freshly cut stems. Only a slight thickening of xylem vessel wails could be observed after 4 days of storage at 4 ± 1°C and on the third day in vase. At senescence, there was severe thickening of xylem vessel walls. The "Raktagandha" cut roses stored for 4 days at 4 ± 1°C without any pulsing also showed a slight thickening which increased at senescence [30].

**Chemical treatments**: A diverse array of treatment chemicals have been recommended for use with cut flowers. Most are proprietary materials, of unknown formulation. Before adopting any particular chemical for use in a commercial operation, it is strongly recommended that you evaluate several different materials. High price is not necessarily equated with effectiveness. The preparation of the solutions listed below requires a little more effort than purchasing a pre-mixed formulation, but they will certainly be less expensive.

**Pulsing with sugar:** Sugar pulses will improve vase life and opening of many flowers. Spectacular results

are obtained with spike-type flowers such as gladiolus and tuberose which need food for opening tight buds. The sugar can be regular cane sugar or corn sugar. If you can get liquid sugar cheaper, you can calculate the required amount from the concentration in the syrup specified by the supplier. In addition to the sugar, pulsing solutions should contain an acidulant and a biocide. It can simply add the sugar to your regular preservative, or use one of the following: Required amount of sugar + 0.3 oz citric acid + 0.2 oz 8-HQC per 8 gallons of water (Required amount of sugar + 1 g citric acid + 0.7 g 8-HQC per litre of water) suits most flowers.

**Pre-treatment with STS:** The STS concentrate is prepared by first dissolving 5.5 oz of anhydrous sodium thiosulphate or 9 oz of prismatic sodium thiosulphate into a clean plastic bucket containing one quart of water. 1.3 oz (40 grams) of silver nitrate is then dissolved into a separate bucket containing a quart of water. The stock solution is completed by flowly pouring the silver nitrate solution into the sodium thiosulphate solution, stirring rapidly as the solutions are mixed. Add ¼ or Physan-20 to the solution. This stock solution should be stored in a dark bottle. The working solution of STS is prepared differently depending on the treatment technique:

**Short term pulsing:** Add 4 oz of STS concentrate to 1 gallon of water. Pulse the flowers for 10 to 20 minutes at room temperature. Flowers treated in this way must be immediately rinsed and placed in a preservative solution for at least 1 hour.

**Long term pulsing**: Add 1 oz of STS concentrate to 1 gallon of water. Pulse the flowers for 1 hour at room temperature or overnight in the cooler. You can add the STS to a pulsing solution if you wish. With carnations, a 10% sugar, 1 oz/gallon STS treatment in the cooler overnight has proved quite effective.

**Pre-treatment with silver nitrate:** Used as a pulse pretreatment (a 10 second dip is usually enough), silver nitrate is a very effective treatment for some flowers. Use 1/10 oz per 8 gallons to prepare a 100 ppm solution (1 oz per gallon for a 1000 ppm solution). This material must be prepared with demineralized, distilled or deionized water.

**Biocides:** Biocides used for cut flowers are truly effective in killing the microorganisms present in vase water. 8-hydroxyquinoline citrate and 8-hydroxyquinoline sulfate, which are the most commonly used biocides, prevent rapid growth of bacteria, but do not kill them. Physan-20, a mixture of quaternary ammonium compounds (200 ppm), is an effective biocide, but it is toxic to some flowers (causes bleaching of the stems and may reduce vase life). This material is recommended for handling carnations, gypsophila and even chrysanthemums. The most effective biocide in is silver nitrate. This can be used as a quick dip (100 to 1000 ppm, depending on the flower being treated), or as a component of the preservative solution (25 to 50 ppm, normally). The chloride present in most tap water will reduce the effectiveness of the silver nitrate. The best biocide for commercial application is probably hypochlorite, the main ingredient in household bleach. Most flowers can tolerate low concentrations (20 – 50 ppm) of "chlorine" in a preservative. The problem is that it quickly disappears from the solution and must be replenished regularly. Slow release swimming pool compounds have been used for preparing flower preservatives, but have not proved very popular. One problem with these materials is that they will reduce the acidity of the solution, so extra acid must be added to allow for this [33].

**Table 1. Germicides used in Floral Preservatives**

| Name | Used Symbol | Range of concentration |
|---|---|---|
| 8-Hydropxy Quinoline Sulphate | 8 HQS | 200 – 600 ppm |
| 8-Hydroxy Quinoline Citrate | 8 HQC | 200 – 600 ppm |
| Silver Nitrate | $AgNO_3$ | 10 – 200 ppm |
| Thiobendazole | TBZ | 5 – 300 ppm |
| Silver thiosulphate | STS | 0.2 – 4 mM |
| Quarternary ammonium salt | QAS | 5 – 300 ppm |
| Slow release Cl compound | --- | 50 – 400 ppm |
| $AlSO_4$ | $Al_2 (SO_4)_2$ | 200 – 300 ppm |

**Ethylene inhibitors**: AVG- Ammonia ethoxy vinyl glycine and MVG-Methoxy vinyl glycine are costly. Whereas another ethylene inhibitor (EI) – Amino ethoxy acetic acid (AOA) is cheap but less active. Silver thiosulphate is another commonly used EI. These ethylene inhibitors prevent premature or undesirable abscission and sleepiness. They also reduce the action of ambient ethylene as well as catalytic production of ethylene by flowers.

**Nanotechnology for ethylene control:** Nanotechnology can be defined as the design, characterization, production and application of

structures, devices and systems bycontrolling the shape and size at the nanometer scale [27]. Nanotechnology exploits the particular characteristics of nano-particles (structures of 1–100 nm dimensions) and can be a very useful technology in a wide range of branches in science and industry. Understanding and controlling matter at the nanoscale interests researchers in the sciences, medicine, agriculture and industry because a material's properties at the nanoscale can be very different from those at a larger scale [5]. Uses of nanotechnology aim to increase production and decrease postharvest wastage. Nano-particles and nano-porous materials can be used to carry ethylene action inhibitors, control growth and development of microorganisms and introduce a new generation of packaging coverage that controls gases and harmful UV rays while increasing strength, quality and packaging appearance [5]. Recent results on the use of nanotechnology for cut flower vase life improvement, focusing on ethylene control.

***Growth regulators***: Play a major role in senescence of cut flowers, by affecting maintenance of flowers and production of ethylene usually coincides with the onset of respiratory climacteric in flower crops like carnation, hibiscus etc. Thus the post harvest life of cut flower is not dependent on a single factor. Proper technologies have to be formulated for enhancing the post harvest life of cut flowers and thereby the development of cut flower industry.

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