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POSTHARVEST BIOLOGY AND TECHNOLOGY OF ORNAMENTALS

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Abstract: *Cultivation of flowers and ornamental crops is a rapidly expanding dynamic global enterprise in today's world. Flowers are closely associated with our culture, civilization and social activities. Handling of flowers (loose and cut), cut greens and potted plants is a very huge task even today. The interaction between the different parts of flower and plant decides their rate of senescence. Flower petals are generally short lived and the existence of petals determines the effective life of cut flowers. Retaining the freshness and turgidity and improving the vase life and flower quality are essential for post harvest management of flowers.Losses in quantity and quality affect horticultural crops between harvest and consumption. The magnitude of postharvest losses in fresh flowers, fruits and vegetables is an estimated 5 to 25% in developed countries and 40 to 60% in developing countries, depending upon the commodity, cultivar, and handling conditions. To reduce these losses, producers and handlers must first understand the biological and environmental factors involved in deterioration, and second, use postharvest techniques related to commodity that delay senescence and maintain the best possible quality. Fresh fruits, ornamentals and vegetables are living tissues that are subject to continuous change after harvest. While some changes are desirable, most-from the consumer's standpoint-are not. Postharvest changes in fresh produce cannot be stopped, but they can be slowed within certain limits. Senescence is the final stage in the development of plant organs, during which a series of irreversible events leads to breakdown and death of the plant cells. Fresh horticultural crops are diverse in morphological structure (roots, stems, leaves, flowers, fruits, and so on), in composition, and in general physiology. Thus, commodity requirements and recommendations for maximum postharvest life vary among the commodities. All fresh horticultural crops are high in water content and are subject to desiccation (wilting, shrivelling) and to mechanical injury. They are also susceptible to attack by bacteria and fungi, with pathological breakdown the result. Molecular analysis has proved a large number of aspirant genes responsible for senescence and remobilization. Future research work will conclusively focus on providing better planting material by using traditional, genomic assisted, and/or molecular breeding approaches for improving the postharvest performance of ornamental plants.*
Keywords: *Ornamentals, cut flowers, loose flowers, post-harvest treatment.*

Introduction: In the past 50 years, the cut flower market has changed dramatically, from a local market with growers located on city outskirts, to a global one; flowers and cut foliage sourced from throughout the world are sold as bunches or combined into arrangements and bouquets in the major target markets, such as North America, Japan, and the European Union. Items in a single florist arrangement are often sourced from countries in three or more continents. The high value of cut flowers has driven major increases in production in many developing countries. Production of cut flowers and foliage can be highly profitable in countries with an ideal growing environment (particularly those close to the equator where the environment is uniform throughout the year), and labour costs are low. The costs of establishing production in the field or even in plastic houses are relatively modest, and harvest may start within a few months of planting. This reshaping of the market has occurred with little consideration for its postharvest consequences. Flowers that used to be obtained from local growers and were retailed within days of harvest may now take as long as three weeks to arrive at the retail florist or supermarket. Increased emphasis on holidays as occasions for sale of cut flowers has exacerbated this trend. The volume of flowers required to meet the demand for the major holidays (Valentine's Day, Mothers' day) has led to widespread storage. The peak in harvest of roses for Valentine's Day in Central America, is three weeks prior to the holiday itself!

Because of their perishability, flowers and foliage produced in distant growing areas have traditionally been shipped by air (a transportation system whose rapidity fails to offset the disadvantages of poor temperature management and low humidity). The net result, especially in India, has been a reduction in display life of cut flowers and foliage, disenchantment with the cut flower purchase experience, documented in many surveys, and a per capita consumption of cut flowers in the India that is less than that in almost all other developed countries [1]. Cut flowers, loose flowers, bulbs, perennial flowers, ornamental plants, landscape and gardening, floral arrangements, and specific decorations are among important business areas currently practiced under floriculture sub-sector in India. Over the past two decades production pattern is changing according to consumers demand and preference behaviours as well as global market scenarios. Since early Nineties, cut flower production system flourished especially with gladiolus and roses. Currently more than 50 cut flowers are available in Indian market. Among these 5 cultivars viz. gladiolus, and local roses are grown in open areas and Dutch rose, carnation and gerbera are cultivated under protected condition and are available round the year. Whether you grow fresh flowers for the local farmers' market and retail florist or have a large operation that sells truckloads to the national wholesale market, you need to move your product from the field to your consumers in a manner that ensures a high quality product. Below are the top 10 reasons why flowers do not last.

1. Food depletion
2. Attacked by bacteria and fungi
3. Normal maturation and aging
4. Wilting- water stress and xylem blockage
5. Bruising and crushing
6. Fluctuating temperatures during storage and transit
7. Colour change- bluing
8. Accumulation of ethylene
9. Poor water quality
10. Suboptimal cultural practices or conditions

Cold storage and proper attention to maintaining optimum cold storage temperatures will slow normal maturation and aging, attack by bacteria and fungi and bluing of flowers, besides solving any improper temperature control problems. Consistent use of floral preservatives, careful handling and good sanitation practices will solve food depletion, poor water quality, bruising and crushing, wilting, and bacterial and fungal attack problems. Ethylene accumulation can be handled by using silver thiosulfate, by having good sanitation practices and good ventilation. Lastly, suboptimal cultural practices and conditions can only produce substandard flowers. You cannot improve the quality of flowers after harvest. Postharvest handling of cut flowers includes both harvest and handling. Harvest includes the decision of when, how and where to cut and the actual act of cutting the flower. Handling is everything else involved in preparing the flowers for market. Exactly how these steps are done depends on the crop, the market and the operation size [1].

Factors Affecting the Postharvest Life of Ornamentals: The intersection of art, design, and horticulture represented by the ornamental plant industry has led to the use of a very wide variety of plant organs and taxa for ornamental purposes. This diversity of taxa, physiological state, and organ means that generalizations about their biology and even technology are often misleading. In this chapter, we focus largely on cut and potted flowers and foliage. Some ornamentals, particularly potted and cut foliage can be extraordinarily long-lived. The *Aspidistra* of Victorian parlors have been replaced in our time by immortal *Scindapsis (Pothos)* plants that trail through offices and hotel lobbies everywhere. Nevertheless, the majority of the ornamentals of commerce have relatively short lives. The delicate petals of flowers are easily damaged, and are often highly susceptible to disease. Even under optimum conditions, their biology leads to early wilting, abscission, or both. Foliage is longer lived, although the low light of the postharvest environment frequently leads to early leaf yellowing, and, in some cases, leaf abscission. As with other perishable horticultural crops, the life of ornamentals is affected by physical, environmental, and biological factors. After harvest, temperature is of over-riding importance, and affects plant water relations, growth of disease, response to physical stresses, carbohydrate status, and the interplay among endogenous and exogenous growth regulators. Much has been learnt in the past 40 years about the role of these factors and the response of ornamentals to them, and some of the research findings have led to technologies that can greatly improve marketing and postharvest quality of ornamentals.

a. Harvest: The most important factors for harvest are when, how and where-"when" the plant material will reach the optimum stage of development and "when" during the day to harvest. Each plant material has its own best harvest stage and this can vary depending on the use of, and market for, the plant material. Materials for preserving usually are harvested more mature than those for fresh, wholesale markets. Some general rules of thumb for when to harvest are: spike type flowers- harvest when one-fourth to one-half of the individual florets are open; daisy type flowers- harvest when flowers are fully open. These are for a national whole sale market. For local markets, the material can be more mature. The other "when" is, when is the best time of day for flower harvesting. The best time is the coolest part of the day and when there is no surface water from dew or rain on the plants. Also, harvesters need enough light to see what they are harvesting. This usually is in the cool of the morning after the dew has dried. Late afternoon or evening also has possibilities because the plants have stored carbohydrates from the day which will provide a food reserve for the plant material. "How" and "where" go together. Besides knowing at what stage of development to harvest, where and how to cut the flower on the plant also is important. This is most important on plants that produce multiple flowers/crops per season. You want to harvest the longest stem possible without sacrificing future production. You should leave at least two to five nodes (growing points) below your cut to ensure new growth. Very vigorous plants can be cut back to less nodes, while less vigorous plants should have more nodes left. Most stems should be at least 15 to 18 inches long. Longer lengths usually are better. It does not matter if the cut is slanted or squared, but it does matter that you use sharp, clean cutting utensils. Sharp cutting utensils will not crush the xylem and block the flow of water up the stem. Hygienic utensils will not introduce harmful microbes to the cut stems. Some shears are designed to hold the flower after it is cut. Cutting utensils should be cleaned daily with disinfectant- a 1:10 solution of chlorine bleach in water works well. Flowers with sticky sap require some special treatments immediately after harvest. To prevent the flow of the sticky sap, which can block the xylem, dip the cut ends in boiling water for 10 seconds or sear with a flame, immediately after harvest. Poppies, mignonette and poinsettia are examples of flowers having sticky sap.

b. Handling: Once harvested, there are a series of steps or tasks done to prepare the flowers for market. These are collectively called handling. These handling steps include:

1. Grading
2. Leaf Removal
3. Bunching
4. Re-cutting
5. Hydration
6. Special Treatments
7. Packing
8. Pre-cooling
9. Cold Storage
10. Delivery to Market

Not all of these are done to all flowers, and whether they are used or not depends on the market the flowers are going to be sold to. Where and how the steps are done depends on the market and the facilities of the operation. Flowers can have all the handling steps performed in the field, only some done in the field with the rest in the packing house, or have all handling practices done in the packing house. Field handling usually is limited to leaf removal, grading, bunching, hydrating, and packing with immediate transport to market or cold storage for brief holding. Flowers for local retail markets often are packed this way since they are marketed immediately after harvest. Flowers also can have these steps performed in the field and then be transported to a packing shed where re-cutting, special treatments, pre-cooling and dry packing can be performed. All the handling steps can be done in a packinghouse, too. It often makes for a better flow of activities if they are all done in the same place. Some of the steps can only be feasibly done in the packinghouse, such as special treatments, pre-cooling, cold storage and re-cutting. These extra steps usually are done for flowers going to wholesale markets. The packing section may be an ultra modern air conditioned building or an open air covered porch. The handling space should:

- Be shaded or covered to keep temperatures lower and prevent direct sunlight on the flowers.
- Be well lit so you can see well when grading the flowers.

- Have a clean water source for preparing harvest, treatment and holding solutions, and for use in cleaning the area.
- Have ample space so all handling activities can be performed smoothly, such that workers are not crossing over each other.
- Have a cold storage or at least a cooler, shaded place to store the flowers until they are ready for market.
- Have a place to prepare for harvest activities.

Although not previously listed, the first step after cutting the stem, whether you are going to handle them in the field or in the packing shed, should be to place them in water or a harvest solution. This solution may be acidified (pH 3.5), tepid water, citric acid works well, or a floral preservative. The harvest containers should be clean and disinfected after each use. Flowers should never be laid on the bare ground. After the harvest container is full of flowers, place them in a cool place until they can be handled or taken to market. The cool place can be a shady area in the field or a refrigerated cold storage. Do not over fill the containers. This will bruise your flowers and cause some to tangle with each other. Leaves should be stripped from the stem. If the flowers are being field handled this can be done before they are placed in the harvest containers or before they are bunched into marketable bouquets. Usually, leaves are stripped from the bottom one third of the stem, or at least the ones that would be in any holding solution.

c. Grading: Grading starts with deciding which flowers to harvest. Only marketable flowers should be harvested. Marketable flowers are free of blemishes, including both leaves and petals. The flowers can be grouped or graded by stem length if there are differences and also by developmental stage. More mature ones should be sold as soon as possible, while others can be held in cold storage for later sales accordance to the demand of market. How the flowers are bunched and packaged depends on the market you are using. If you are selling in a local retail market you have a lot of flexibility, but customers will let you know what sells the best. Mixed bunches and single type bunches are both popular. Bigger flowers such as lilies, gladiolus and sunflowers often are sold as single stems. Sleeving or wrapping the bunches helps prevent the different bunches and flowers from becoming tangled. Columbine, larkspur, delphinium, baby primrose, forget-me-nots and buddleia are flowers that should be wrapped or sleeved prior to marketing to prevent tangling. Wholesale markets have a set of guidelines for the methods of bunching and packaging flowers. Most are bunched by 10‘s or 5‘s. Some, like roses and carnations, are bunched by 25‘s. Lilies-of-the-Valley are bunched in 25‘s and Sweet Violets are bunched in 100‘s with a collar of leaves underneath the flowers. Large, expensive to grow flowers can be sold by single stems. As stated before, some should be wrapped to prevent tangling. Most are boxed and shipped dry. Proper pre-shipping handling is important in order to get flowers to the market in good shape. The flowers should be well hydrated but not wet when packed. Most spike flowers like snapdragons and gladiolus need to be packed upright to prevent the tips from curving. Special boxes or hampers are made for these types of flowers. Once bunched, flowers should be hydrated, placed in water for awhile before they are packed dry. The hydrating step should include a step where, after the flowers are bunched, the stems are recut under water to eliminate any air bubbles in the xylem that can block the uptake of water. These air bubbles can occur when the flowers were harvested. Once recut, the flower can be placed in a general holding solution used to hydrate the flowers or receive a special treatment such as silver thiosulfate. The standard flower box is 12 x 12 x 48 inches. There are smaller sizes, too, called half or quarter boxes that are 6 x 12 x 48 inches and 6 x 6 x 48 inches, respectively.

d. Pre-cooling: Pre-cooling is a step that rapidly brings the temperature of the flowers down from the field temperature to a proper storage temperature. A low temperature slows the respiration rate of the flowers which in turn helps them last longer. Forced-air cooling is the best method for flowers-cool air is actively forced with fans through the bunched flower. This can be done when the flowers are in a bucket or when they are packed dry into boxes. The pre-cooling of flowers is a very important step for individuals selling to a large wholesale market, distant markets and if their crop is to be stored for a long time such as peonies. Individuals who sell at a local retail market usually do not need to worry about this step since their flowers will be in the customer’s home the day they are picked.

e. Cold Storage: Cooling is recommended for all flowers that will not be in the market immediately and any flowers sold wholesale. As stated before, low temperatures slow the respiration rate of the flowers and prolong the vase life of the flowers. In general, temperatures should be 32 to 40^{o}F and have a relative humidity of 85 to 90 percent, for most flowers. Flowers should never be stored with fruits and vegetables. Some fruits and vegetables produce ethylene that can dramatically shorten the life of the flowers. Once flowers are bunched into market able units they should be placed in cold storage. Flower storage life and vase life are considered to be two different things. The customer wants to know the vase life - how long will the flowers last in my home - while the grower needs to know both - to determine how long flowers can be kept in cold storage and to be able to tell customers how long the flowers will last. If flowers have to be stored before marketing, a cool place (preferably a refrigerated cold storage, especially for flowers) should be used. There are many flowers that are not commonly found in the wholesale market because they do not store well, ship well or last long. These should only be used for local markets. These include foxglove, garden phlox, lupine, clarkia, stevia, common stocks, candytuft, cornflower, feverfew, blue lace flower, English daisy, calendula, pot marigold, sweet violets and gaillardia.

f. Fresh Flower Preservatives: These are chemicals added to water to make flowers last longer. They contain a germicide, a food source, a pH adjuster, water, and sometimes surfactants and hormones. Germicides are used to control bacteria, yeasts and molds. These microorganisms infect the flowers by producing ethylene, blocking the xylem, producing toxins and increasing sensitivity to low temperatures. 8-HQC is the most common one used in commercial floral preservatives. Sucrose is the most common food source used in floral preservatives. It provides energy to sustain flowers longer and to open flowers in the bud stage.1 to 2 percent sucrose is the standard amount in preservatives. Never use sucrose without a germicide, as it is the primary food source for microorganisms, too. Acids or acid salts are added to adjust the pH of the water to 3.5 to 5.0. At this pH, fewer microbes can grow and water is taken up by the flowers more easily. Surfactants and wetting agents reduce water tension so water is taken up more easily, also. We take water and its quality for granted. We expect it to be pure and healthy for our flowers, but that is not always the case. Water is what keeps flowers turgid or firm. There are some properties or characteristics of water that should be understood because of their effect on flowers. They are pH, temperature, soluble salts, alkalinity and hardness. As stated before, acidic water, pH 3.5 to 5.0 is best. Water with a low pH is taken up by the flowers quicker and more easily. The lower pH inhibits the growth of xylem blocking microbes. Neutral is 7, acidic is <7, and basic is >7. Citric acid, an organic acid, usually is used to acidify water. The best temperature is warm-100^{o}F. Warm water has less dissolved gases in it-dissolved gas bubbles can cause blockages in the xylem just like microbes. Unless water is pure, it will have dissolved mineral salts in it; these will affect the pH and contribute to the salinity, hardness and alkalinity of the water. When water is tested, the results will usually show a total soluble salts or total dissolved salts number. This usually is expressed as ppm or mg/liter or microsiemans. These are not interchangeable.

1 ppm = 1 mg/liter = 700 µ siemans

The total soluble salts are made up of alkalinity or hardness and salinity. Low soluble salt content is best. They can interfere with water uptake because they change the osmotic potential of the water. They can burn leaves and petals because they can accumulate in the tips. Alkalinity is the measure of water's ability to neutralize acid or buffering capacity. It is a measure of the negative ion salts in the water. It is measured as mg/liter Calcium Carbonate, $CaCO_3$ equivalents or ppm Calcium Carbonate, $CaCO_3$. The active ions are bicarbonate, HCO_3- ; carbonate, CO_3=; and hydroxide, OH=. Water with less than 100 mg/litre $CaCO_3$ equivalents is best. If it is higher, the pH of the water may not be able to be adjusted with a floral preservative; and will make the floral preservatives ineffective since the acidifiers in them may be completely "buffered out" by the alkalinity of the water. To make the floral preservative more effective, an acid such as citric acid will need to be added instead of adding more floral preservative. Hardness often is used interchangeably with alkalinity but it measures the positive ion salts in the water. These are usually magnesium, Mg++ and calcium, Ca++. The standard practice to decrease hardness in water is to soften it by exchanging the magnesium and calcium ions with sodium ions.

Floral preservatives are designed to deal with less than optimum water. The pH adjusters are designed to lower the pH to the optimum. Some have more acid to deal with "hard" water. Other times the soluble salt content, fluoride levels and alkalinity are so bad a reverse osmosis, deionizing or distillation water system will be needed to purify the water. Pure water has no contaminants; no soluble salts, no fluoride, and no buffering affect so preservative pH adjustor's work well. Water should be tested to determine what the problem is and to determine the best remedy.

Besides the standard floral preservative solutions for holding flowers there are some specific solutions and treatments that serve different needs.

- A harvesting solution often will simply be water acidified with citric acid to a pH of 3.5 to 5.0.
- A conditioning, hardening, or hydrating solution is used to restore the turgor of wilted flowers and dry packed flowers. It usually is warm water with a germicide, acidified to pH 3.5 to 5.0 with citric acid and a wetting agent, i.e. Tween 20 (0.01 to 0.1 percent).
- Impregnation is a treatment that protects stems against the blockage of water vessels by microbes. Stems are dipped in 1000 ppm silver nitrate solution for 10 minutes. The stems should not be re-cut after treatment.
- Pulsing or loading is a type of treatment used to extend the vase life of flowers held in water, stored wet or dry for long periods or shipped long distances. It is called a pulse because it is only done for a short period of time, or called loading because the flowers are loaded up with food for a long storage period. Stems are placed in solutions with germicide and a higher concentration of sugar for specific treatment periods depending on the species. Because the higher concentration of sugar can act like a soluble salt causing petal and leaf injury, the treatment is only a few hours or a day. The temperature should be 65 to 75°F and light intensity should be 2000 lux.
- Bud opening solutions are used to open the flowers harvested at tight bud stage. Flower sharvested at the tight bud stage will keep longer in storage and will transport better. Stems are placed in solutions containing higher concentrations of sugar, plus a germicide and hormonal compounds that facilitate bud growth and development. High light and humidity, and room temperatures are used. The high sugar content can injure the flowers and leaves.

g. Ethylene: Ethylene called the ripening, senescence and wound hormone, is a naturally occurring plant hormone. It is important in the reproductive cycle of plants. It triggers the ripening and senescence of flowers and is also produced when plants are wounded. Many decay and disease organisms also produce ethylene. Ethylene damages some cut flower species by causing flowers to drop prematurely, flower buds to not open, and flower petals to close. Some specific measures to prevent ethylene damage on flowers are:

1. Make sure CO_2 generators in greenhouses and oil or gas heaters in greenhouses and handling areas are working properly and well vented.
2. Protect plants against pest and diseases.
3. Prevent pollination of flowers.
4. Harvest flowers at optimum stage.
5. Avoid physical injury to flowers during handling.
6. Cool flowers as soon as possible after harvest.
7. Keep storage and handling facilities clean, and remove diseased and dying plant material.
8. Do not use internal combustion engines in any handling work or production areas.
9. Have good air circulation and ventilation in handling and storage areas.
10. No smoking in handling and storage areas.
11. Do not store flowers with ethylene producing fruits and vegetables.
12. Do not store newly harvested flowers in bud stages with fully open flowers.
13. Use ethylene scrubbers in cold storage area.
14. Use STS treatment on sensitive species.
15. Use other chemical treatments in floral preservatives.

There are various chemicals that can inhibit the effect of ethylene. The most common is the metal ion silver. It usually is applied to flowers in the form silver thiosulfate(STS). It acts on both ethylene receptors and production sites in the flower. Thisprotects the flowers from ethylene in the environment and it stops the flower from producingethylene itself. Other chemicals are MCP (1-methylcyclopropane) a gas which acts only on receptors, but is not available commercially, and EVB (Pokon& Chrystal), and Vita Flora which act on the flower's ethylene production sites. To treat or pulse flowers with STS, stems a replaced in STS solution for 20 minutes at 65°F.

h. Abscisic Acid: There is substantial published evidence implicating ABA in the regulation of perianth senescence. Not only have researchers shown a close association between petal senescence and increased petal ABA concentrations [2, 3, 4], but exogenously applied ABA has also been shown to accelerate the senescence of a number of flowers [5-9]. Such application results in many of the same physiological, biochemical, and molecular events that occur during normal senescence [9]. In ethylene-sensitive flowers such as carnation flowers and roses, ABA-accelerated senescence appears to be mediated through induction of ethylene synthesis, since it is not seen in flowers that are pre-treated with ethylene [8, 10, 11]. This is consistent with the pattern of endogenous ABA content in rose petals, where the increase in ABA concentration occurs2 days after the surge in ethylene production [7].

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