

# HANDLING OF CUT FLOWERS FOR AIR TRANSPORT

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In the past thirty years, the market for cut flowers has become 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 EU. The high export value of cut flowers has led to dramatic 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 low labor costs. 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. Because of this global production system and marketplace, and the high perishability of cut flowers, air transport has been the transport system of choice. The purpose of this chapter is to provide information on the factors that affect the postharvest life of cut flowers and foliage, to indicate critical control points in the air

transport logistics that impact the life of these delicate products, and to suggest best practices for ensuring optimal out-turns after air freight.

Concise, practical guidelines for shippers handling cut flowers by air are needed to ensure an industry-wide standard of excellence. Industry analysts stress the importance of quality and reliability in the increasingly competitive global market for cut flowers. The most important aspect of quality is 'freshness' and vase life, and these aspects depend on optimum postharvest handling. The first section of this guideline reviews the most important factors affecting postharvest quality of cut flowers and other ornamentals. The second section outlines standard techniques applicable to the commercial handling of most cut flowers by air, and includes suggestions for improving present postharvest handling.

The guidelines rely largely on research that has been published in the scientific literature on optimum handling methods for cut flowers. We are indebted to Dr George Staby, Perishables Research Organization, Pioneer, CA., for the use of his computerized database of references on the care and handling of cut flowers. His website ([www.chainoflife.org](http://www.chainoflife.org)) provides an excellent reference for more detailed information on handling systems for individual crops, as well as the general techniques described in this guideline.

## I. WHAT ARE ORNAMENTALS?

A wide variety of plant materials are grown and harvested for their ornamental value including ferns and lycopodiums, gymnosperms (pines, firs, podocarps etc.), and angiosperms (the flowering plants). The products that we think of as ornamentals include those that are cut for their flowers and/or foliage, and those that are sold as potted flowering plants or potted foliage plants. Dormant ornamental nursery plants and propagules, including rooted and unrooted cuttings, bulbs, corms, tubers, and rhizomes also are important perishable crops and require quite specific handling. Because the preponderance of ornamentals shipped by air are cut flowers, these are the major focus of the guideline, but the principles outlined here apply equally to cut foliage, potted plants, and rooted and unrooted cuttings.

## II. QUALITY LOSS IN ORNAMENTALS

Whether cut or intact, ornamentals are complex plant organs, in which loss of quality of stems, leaves, or flower parts may result in rejection in the marketplace. In some ornamentals loss of quality may result from one of several causes, including wilting or abscission of leaves and/or petals, yellowing of leaves, and geotropic or phototropic bending of scapes and stems. In thinking about factors that affect the life of ornamentals and how to extend that life, it's important first to understand the diverse causes of quality loss.

### *Growth, development, and aging*

In plants, death of individual organs, and of the whole plant itself, is an integral part of the life cycle. Even in the absence of senescence of floral organs or leaves, the continuing growth process can result in quality loss, for example in spike-type flowers that bend in response to gravity.

### *Flower senescence*

The early death of flowers is a common cause of quality loss and reduced vase life for cut flowers. Flowers can be divided into several categories in terms of their senescence. Some flowers are extremely long-lived, especially in the daisy and orchid families. Others are short-lived, including many of the bulb crops, like tulip, Iris, and Narcissus.

### *Wilting*

Extended life for cut and potted ornamentals depends absolutely on a continuing and adequate supply of water. Failure of water supply, whether through obstruction of the cut stems, or through inadequate watering of pots, results in rapid wilting of shoot tips, leaves, and petals.

### *Leaf yellowing and senescence*

Yellowing of leaves and even of other organs (buds, stems) commonly is associated with the end of display life in some cut flowers (alstroemeria being an important example). Leaf yellowing is a complex process that may be caused by a range of different environmental factors.

### *Shattering*

Loss of leaves, buds, petals, flowers, or even branchlets, a process called 'shattering', or 'abscission', is also a common problem in cut flowers. Very often, this problem is associated with presence of ethylene in the air, but other environmental factors may also be involved.

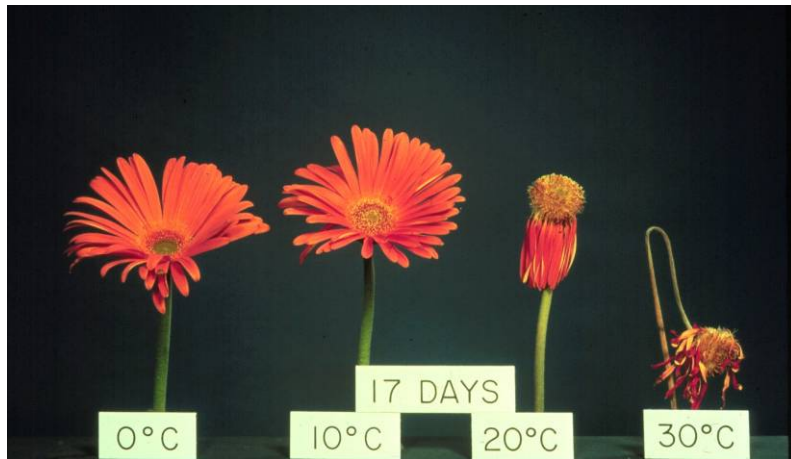
## **III. FACTORS AFFECTING POSTHARVEST QUALITY**

Maintaining quality in air-freighted cut flowers depends on an understanding the factors that lead to deterioration. Understanding these factors allows the grower and shipper to develop and implement optimum postharvest handling technologies.

### *Flower Maturity.*

Minimum harvest maturity for a cut-flower crop is the stage at which harvested buds can be opened fully and have satisfactory display life after distribution. Many flowers are best cut in the bud stage and opened after storage, transport or distribution. This technique has many advantages, including reduced growing time for single-harvest crops, increased product packing density, simplified temperature management, reduced susceptibility to mechanical damage and reduced desiccation. Many flowers are presently harvested when the buds are starting to open (rose, gladiolus), although

others are normally fully open or nearly so (chrysanthemum, carnation). Flowers for local markets are generally harvested much more open than those intended for storage and/or long-distance transport.



The optimum storage temperature for most cut flowers is 0 C. Flowers kept at 20 C deteriorate nine times faster than those kept at 0 C.

### *Temperature.*

Respiration of cut flowers, an integral part of growth and aging, generates heat as a by-product. Furthermore, as the ambient temperature rises, the respiration rate increases. For example, a flower held at 30°C is likely to respire (and therefore age) up to 45 times as fast as a flower held at 2°C. The rate of aging can be reduced dramatically by cooling the flowers. Rapid

cooling and maintenance of the cool chain are thus essential for maintaining quality and satisfactory vase life of cut flowers.

Although air transport is rapid compared to surface modes (truck, sea container, etc.), the response of cut flowers and foliage to temperature leads to their rapid deterioration even during the relatively few hours that they are in transit when transported by air. It has frequently been demonstrated that transport of flowers in surface modes that permit maintenance of the cold chain results in better out-turns than air freight under uncontrolled temperatures. This is largely a result of the dramatic response of flowers to increased temperatures. For this reason, air transport is seldom the method of choice when alternative transportation modes that offer good control of temperature are available. The purpose of this guide is to sensitize those involved in air transport of flowers to the importance of the cool chain to flower quality, and to suggest strategies to improve temperature control during air transport.

The accompanying photographs demonstrate the effect of storage for four days at different temperatures on the subsequent quality and vase life of some common cut flowers. One day after removal from storage, the quality of gerberas is clearly highly related to injurious temperatures. The bending of the scapes in these flowers is the result of negative geotropism (bending away from gravity) which is accelerated by storage at warmer temperatures. In snapdragons the effect of storage at different temperatures is seen dramatically after four days at room temperature. Flowers held at temperatures warmer than the optimal (0°C) show marked loss of quality with increasing storage temperature. Bent stem tips, loss of lower florets, and reduced opening of young buds are seen in flowers that are stored at warm temperatures. A similar picture

is seen in lilies stored at different temperatures for four days and then held for two days at room temperatures.

It has been suggested that the striking effects of temperature could be overcome by holding the flowers during storage in water - using so-called 'aquapacks' or Proconas™. Research shows that this is only partly true. Yes, flowers stored at warm temperatures in water will perform better than flowers stored dry at the same temperatures. However, they do not perform as well as flowers stored dry or wet at the proper storage temperature.

The optimum temperature for storage of most of the common cut flowers is near the freezing point 0°C. Some tropical crops such as anthurium, bird-of-paradise, some orchids and ginger are injured, however, at temperatures below 10°C. Symptoms of this "chilling injury" include darkening of the petals, water soaking of the petals (which look transparent), and, in severe cases, collapse and drying of leaves and petals.

#### *Food Supply.*

Starch and sugar stored in the stem, leaves and petals provide much of the food needed for cut-flower opening and maintenance. These carbohydrate levels are highest when plants are grown in high light and with proper cultural management. Carbohydrate levels are, in fact, generally highest in the late afternoon -- after a full day of sunlight. However, flowers are preferably harvested in the early morning, because temperatures are low, plant water content is high, and a whole day is available for processing the cut flowers.

The quality and vase life of many cut flowers can be improved by pulsing them after harvest with a solution containing sugar. Pulsing is done by standing the cut flowers in solution for a short period, usually less than 24 hours, and often at low temperature. Typical examples are tuberose, where storage life and opening are dramatically improved by a sugar pulse, and gladiolus, where sugar-pulsed flowers to open further up the spike, are bigger, and have a longer vase life. Sugar is also an important part of the bud-opening solution used to open bud-cut flowers before distribution, and as part of the vase solution used at the retail and domestic level.

#### *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, alstroemeria, marguerite daisy and other crops can yellow if stored in darkness at warm temperatures. We have shown that the blackening of leaves of cut flowers of *Protea nerifolia* can be prevented by maintaining the flowers in high light or by treating the harvested flowers with a sugar pulse. This suggests that the problem is induced by low carbohydrate status in the harvested inflorescence.

#### *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 humidities 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 air transportation or long-term storage) they can be fully rehydrated using proper techniques. Cut flowers will absorb solutions without difficulty providing there is no obstruction to water flow in the stems. Air embolism, bacterial plugging, and poor water quality are factors that can reduce solution uptake.

*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 recutting the stems under water (removing about 1 inch), ensuring that the solution is acid (pH 3 or 4), by placing the stems in a vase solution heated to 40°C (warm, but not hot), by placing the stems in an ice-cold vase solution, by briefly (10 seconds to 10 minutes) dipping the stems in a weak detergent solution (for example 0.02% of dishwashing liquid), or by deeply immersing the stems in solution (at least 20 cm (8")).

*Bacterial plugging.* The cut surface of a flower stem releases the contents of the cut cells, proteins, amino acids, sugars, and minerals into the vase water. These are ideal food for bacteria, and these minute organisms grow rapidly in the anaerobic environment of the vase. Slime produced by the bacteria, and the bacteria themselves, can plug the water-conducting system. This problem must be addressed at every step of the postharvest chain.

- Use clean water for making postharvest solutions – dirty water contains millions of the bacteria that will proliferate at the base of the flower stem.
- Buckets should be cleaned and disinfected regularly – dirt harbors bacteria and may protect them from germicides. Wash thoroughly with a detergent, rinse in clean water, and give a final rinse with a solution containing 1 ml Clorox (5% hypochlorite) per liter of water. Preferably every time the bucket is used. Don't stack buckets if the outside isn't as clean as the inside!
- Use white buckets – dirt is easier to see in a white bucket.
- Bucket and vase solutions always should contain a 'biocide', a chemical that prevents the growth of bacteria, yeasts, and fungi. Common bucket biocides are calcium or sodium hypochlorite, aluminium sulphate, and salts of 8-hydroxyquinoline. An acidic solution also inhibits bacterial growth.
- Sugar-containing solutions for pulsing, bud-opening, or display, should contain an adequate germicide.

*Hard Water.* Hard water frequently contains minerals that make the water alkaline (high pH). For some reason, water movement in flower stems is drastically reduced when the water is of high pH. This problem can be overcome either by removing minerals from the water (by using a deionizer, still, or reverse osmosis system) or by making the water acid. Commercial flower solutions may not contain enough acid to acidify some very alkaline waters. In that case, more acid should be added to the water. In some countries, the obvious alternative solution is to use rain-water for postharvest solutions.

### *Water Quality.*

Chemicals commonly found in tap water are toxic to some cut flowers. Sodium (Na), present in high concentrations in soft water, is, for example, toxic to carnations and roses. Fluoride (F) is very toxic to gerbera, gladiolus, roses and freesia; fluoridated drinking water contains enough F (about 1 ppm) to damage these cut flowers.

### *Ethylene.*

Certain flowers, especially carnations, gypsophila 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 calceolaria, 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 (e.g. gasoline, jet fuel, firewood, tobacco). Levels of ethylene above one hundred parts in one billion parts of air (100 ppb) in the vicinity of sensitive 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 thiosulphate complex of silver (STS) or a new gaseous inhibitor, 1-MCP (Ethyl-bloc), reduces the effects of ethylene (exogenous or endogenous) on some. 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, snapdragon, lisianthus, stock, roses, and gerbera, because the flower stems (pedicels) or the main stem bends upward when stored horizontally. Geotropism is greatly reduced when flowers are maintained at low temperatures; where this is not possible, such flowers should be handled upright.



Lisianthus buds bend upwards when held horizontal at room temperatures.

### *Mechanical Damage.*

Bruising and breakage of cut flowers should be avoided. Flowers with torn petals, broken stems or other obvious injuries are undesirable for aesthetic reasons. Disease organisms can more easily infect plants through injured areas. In fact, many disease organisms can only enter a plant through an injury point. Additionally,



respiration and ethylene evolution is generally higher in injured plants, further reducing storage and vase life.

#### *Disease.*

Flowers are very susceptible to disease, not only because their petals are fragile, but also because the secretions of their nectaries often provide an excellent nutrient supply for even mild pathogens. To make matters worse, transfer from cold storage to warmer handling areas can result in condensation of water on the harvested flowers. The most commonly encountered disease organism, gray mold (*Botrytis cinerea*), can germinate wherever free moisture is present. In the humid environment of the flower head, it can even grow (albeit more slowly) at temperatures near freezing. Proper management of greenhouse hygiene, temperature control, and the minimizing of condensation on the harvested flowers all reduce losses caused by this disease. Some fungicides, such as Ronalin, Rovral (Iprodione), and the copper-based Phyton-27 have been approved for use on cut flowers and are very effective against gray mold.

## IV. POSTHARVEST MANAGEMENT TECHNIQUES

Systems for harvesting and marketing cut flowers vary according to individual crops, growers, production areas, and marketing systems. All involve a series of steps - harvesting, grading, bunching, sleeving, packing, pre-cooling and transportation - not necessarily in that order. Management systems should be selected so as to maximize postharvest life of the flowers, a goal which usually requires prompt pre-cooling and proper temperature management throughout the harvesting chain. Increasingly, producers are trying to reduce the number of separate steps in the marketing chain. For example, some field flower growers cut, grade, bunch and pack their product in the field. The packed boxes are then taken directly to the pre-cooler. Such systems, where appropriate, reduce damage to the flowers, and may decrease labor costs.

#### *Harvesting.*



Careful selection for quality and maturity at harvest is vital

Harvesting is normally done by hand using shears or a sharp knife. Simple mechanical aids are used to harvest some crops, for example the hook-shaped "comma" which permits chrysanthemum harvest without stooping, and rose shears which grip the flower stem after it has been cut, allowing it to be withdrawn single-handedly from the bench. At no time should harvested flowers be placed on the ground because of the danger of contaminating the flowers with disease organisms.

Ideally, harvesting, grading and packing should all be done dry, that is to say without the use of chemical solutions or water. If this is not possible, however, clean buckets containing clean water and a biocide should be used. With hard water and for difficult to rehydrate

flowers, clean water containing a biocide and sufficient citric acid to reduce the pH below 5.0 should be used instead.

### *Grading.*

The designation of grade standards for cut flowers is one of the most controversial areas in their care and handling. Objective standards such as stem length, which is still the major quality standard for many flowers, may bear little relationship to flower quality, vase life or usefulness. Weight of the bunch for a given length is a method that has been shown to strongly reflect flower quality. Straightness of stems, stem strength, flower size, vase life, freedom from defects, maturity, uniformity, and foliage quality are among the factors which should also be used in cut flower grading. Mechanical grading systems should be carefully designed to ensure efficiency and to avoid damaging the flowers.

### *Bunching.*

Flowers are normally bunched, except for anthuriums, orchids and some other specialty flowers. The number of flowers in the bunch varies according to growing area, market and flower species. Groups of 10, 12, and 25 are common for single-stemmed flowers. Spray-type flowers are bunched by the number of open flowers, by weight or

by bunch size. Bunches are held together by string, paper-covered wire or elastic bands and are frequently sleeved soon after harvest to separate them, protect the flower heads, prevent tangling and identify the grower or shipper. Materials used for sleeving include paper (waxed or unwaxed), corrugated card (smooth side towards the flowers) and polyethylene (perforated, unperforated and blister). Sleeves can be preformed (although variable bunch size can be a problem), or they can be formed around each bunch using tape, heat sealing (polyethylene), or staples.



Corrugated cardboard sleeves provide excellent cushioning and protection for roses during transport.

Damage through multiple handlings can be reduced if grading, sizing, and even bunching are carried out in the field or greenhouse. Flowers should be graded and bunched before being treated with chemicals or being placed in storage. When the flowers are badly wilted, or when labor is not available for grading and bunching, flowers should be rehydrated and cooled until these operations can be carried out.

### Chemical Solutions.

The various chemical solutions used after harvest to improve the quality of cut flowers usually have specific purposes.

### Rehydration.

Wilted flowers, placed in water to restore turgidity, should be rehydrated with deionized water containing a germicide. Wetting agents (0.01 to 0.1%) can be added, and the water should be acidified with citric acid, HQC, or aluminium sulphate to a pH near 3.5. No sugar should be added to the solution, and rehydration should be carried out in a cooler.

### Pulsing.

The term "pulsing" means placing freshly harvested flowers for a relatively short time (a few seconds to several hours) in a solution specially formulated to extend their storage and vase life. Pulsing solutions are specific to the individual crop. At the present time, they are used to provide additional sugar (gladiolus, tuberose, hybrid statice, lisianthus), to extend the life of ethylene-sensitive flowers (carnation, delphinium, gypsophila), and to prevent leaf yellowing (alstroemeria).

- Sucrose is the main ingredient of pulsing solutions providing additional sugar, and the proper concentration ranges from 2 to 20%, depending on the crop. The solution should always contain a biocide appropriate for the crop being treated.
- Ethylene-sensitive flowers are pulsed with silver thiosulphate (STS). Treatments can be for short periods at warm temperatures (e.g. 10 minutes at 20°C) or for long periods at cool temperatures (e.g. 20 hours at 2°C).
- Alstroemeria and lilies can be pulsed in a solution containing gibberellic acid to prevent leaf yellowing, and this is often a useful pre-treatment.
- Short pulses (10 seconds) in solutions of silver nitrate have proved valuable for some crops. Chinese asters and maidenhair fern respond well to solutions containing 1000 ppm silver nitrate. Other flowers are damaged by these high concentrations, but respond well to 100-200 ppm (e.g. gerberas). The function of the silver nitrate is not fully understood. In some cases it seems to function strictly as a germicide (e.g. chrysanthemums). In all cases, residual silver nitrate solution should be rinsed from the stems before packing.

### Bud Opening.

Bud-cut flowers must be opened in bud-opening solutions before they are sold to the consumer. These solutions contain a germicide and sugar. Foliage of some flowers (especially roses) can be damaged if the sugar concentration is too high. Buds should be opened at relatively warm temperatures (21-27°C), moderate humidities (60-80% R.H.), and reasonably high light intensities (15 – 30  $\mu\text{mol.m}^{-2}.\text{sec}^{-1}$  PAR).

### *Packing.*

There are many shapes of packing containers for cut flowers, but most are long and flat and a full telescoping design (top completely overlaps the bottom). This design restricts the depth of the flowers in the box, which may in turn reduce physical damage of the flowers. In addition, flower heads can be placed at both ends of the container for better use of space. With this kind of flower placement, whole layers of newspaper have often been used to prevent the layers of flowers from injuring each other. The use of small pieces of newspaper to protect only the flower heads, however, is a better practice, since it allows for more efficient cooling of flowers after packing. It is critically important that containers be packed in such a way that transport damage is minimized.

Some growers anchor the product by using enough flowers and foliage in the box so that the package, after banding, holds itself firmly. To avoid longitudinal slip, packers in many flower-producing countries use one or more "cleats". These are normally foam- or newspaper-covered wood pieces that are placed over the product, pushed down, and stapled into each side of the box. Padded metal straps, high density polyethylene blocks, and cardboard tubes can also be used as cleats. The heads of the flowers should be placed 5 – 10 cm from the end of the box to allow effective pre-cooling and to eliminate the danger of petal bruising should the contents of the box shift. Another system commonly employed to secure flowers is an elastic strap, anchored in the base of the box, that is stretched over the stems of the flowers after packing. Some flowers lend themselves to packing in a manner where the stem bases of some bunches are placed against the ends of the box. The rest of the flowers are packed normally (5-8 cm from the end of the box), and the conical shape of typical bunches means that all the flowers are well secured.



Gladioli, snapdragons and some other species are often packed in vertical hampers to prevent geotropic curvature which reduces their acceptability. Cubic hampers are used for upright storage of daisies and other flowers. A proprietary package, the 'Procona™ system uses plastic bases and a cardboard sleeve to allow transport of flowers upright in water. This system is more expensive than traditional boxes, and less volume of product can be packed in it, but the presence of water improves out-turn when flowers are not transported under proper temperature conditions. Because of their weight, low packing density, and propensity to spill water, systems of this type are seldom used in air shipments.

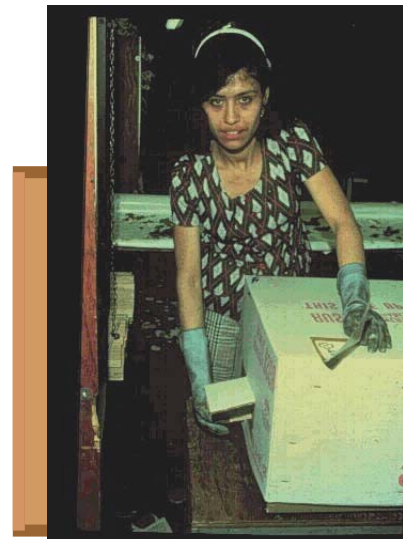
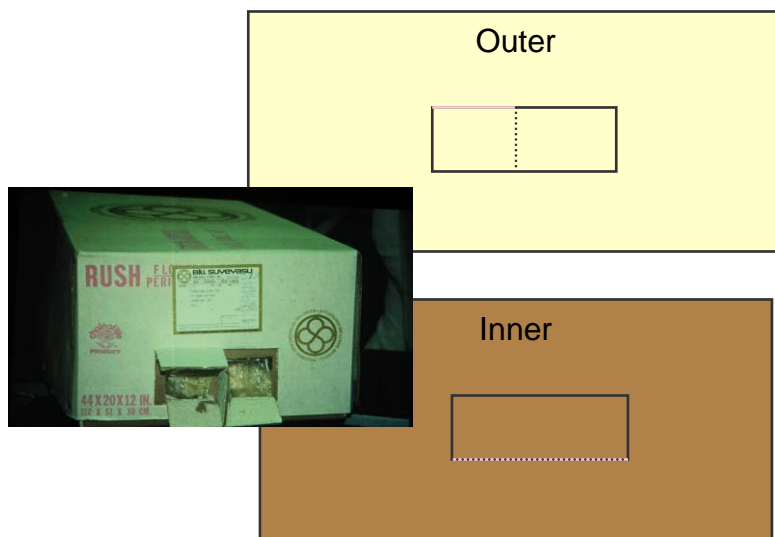
Specialty flowers such as anthurium, orchid, ginger, and bird-of-paradise are packed in various ways to minimize friction damage during transport. Frequently the flower heads are individually protected by paper or polyethylene sleeves. Cushioning materials such as shredded paper, paper wool and wood wool may be distributed between the packed flowers to further reduce damage.



### Box design and construction

Much can be achieved in improving box design and construction. There are literally hundreds of box sizes used in the flower trade, and the quality of card used in the boxes is quite variable. The strength of cardboard falls rapidly at high humidities, and this is why boxes constructed with poor quality card may collapse, particularly where there are major changes in temperature and resultant condensation in the postharvest chain. The industry should move to a small number of box sizes designed to fit the standard international pallet, and should use high quality card. White card speaks of high quality, and allows the grower to highlight the product with printed designs. A major flaw in the design of some boxes is that the pre-cooling vents are pre-formed and not sealed. This means that they become 'fast warming' vents when the box is handled at high temperatures. The standard 'California' box has a simple sealable flap system that is very suitable for flower boxes that may be exposed to ambient temperatures. After pre-cooling the flaps are sealed, and the flowers are thus less exposed to external temperatures.

The flaps on the box provide important extra stiffness to the corners, so if staples are to be used, there should be sufficient (five) to ensure a rigid double sheet of



*Triangular struts in the corners could provide extra strength for flower boxes.*

California flower boxes are constructed with 'pop-out' flaps that provide excellent pre-cooling, but can readily be re-sealed. cardboard. Three up the outside corner, one on the inside bottom corner, and one more or less in the middle of the flap. Many marketing chains no longer permit the use of staples for securing the side flaps of the boxes. Where staples are no longer allowed, replace them with a fast-setting cement (hot glue, for example) with similar placement, rather than a piece of tape around the outside edges. Ingenious folded box designs are now widely used in the produce industry, and an adaptation for flowers would be worth exploring.

One other suggestion for strengthening the box would be to form an extra triangular strut in the corners of the box bottom. Since there is an air-gap between the flowers and the end of the box, the triangle would not reduce packing volume, and would greatly increase corner strength.

### Packing systems

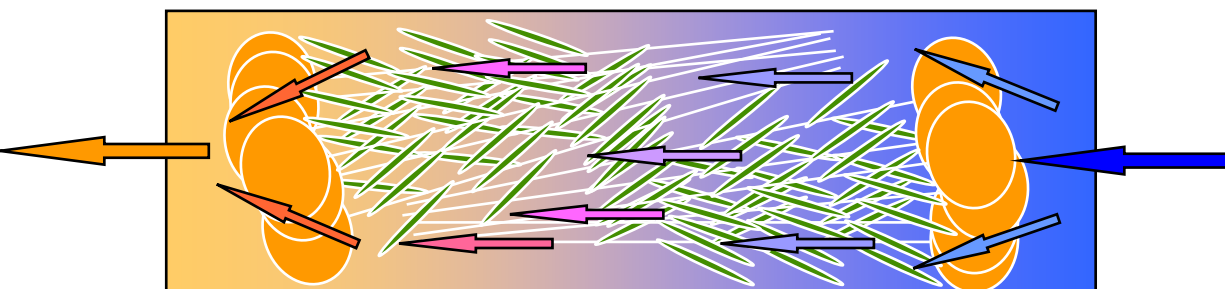
The costing of air transport has led to widespread use of packing systems that are detrimental to good quality in flowers. Because flower freight is typically based on volume rather than weight, producers commonly over-pack their boxes. The result is a rounded box that does not stack well, where the product, not the box, carries the load, which cannot be precooled effectively, and where the box can easily fail. Quality flowers result from packages where the box protects the flowers. Overpacked boxes cannot do that. The pressure to increase the number of flowers in the box explains the tendency to pack the flowers right up to the end of the box. This defeats the forced air pre-cooling system, which depends on a 5-8 cm 'plenum' at each end of the box to distribute the cool air to all the flowers. Warm, bruised flowers, with a poor potential vase life are the inevitable result of this practice.

### Cooling

By far the most important part of maintaining the quality of harvested flowers is ensuring that they are cooled as soon as possible after harvest and that optimum temperatures are maintained during distribution. Most flowers should be held at 0-2°C. Chilling-sensitive flowers (anthurium, bird-of-paradise, ginger, tropical orchids) should be held at temperatures above 10°C.

Individually, flowers cool (and warm) rather rapidly (half-cooling times of a few minutes). So, while individual flowers can be cooled quickly, it is also true that individual flowers brought out of cool storage into a warmer packing area will warm quickly and develop condensation prior to packing. The simplest method of ensuring that packed flowers are adequately cooled and dry is, therefore, to pack them in the cool room. Although this method is not always popular with packers, will probably increase labor cost and may slow down packing somewhat, it ensures a cooled, dry product.

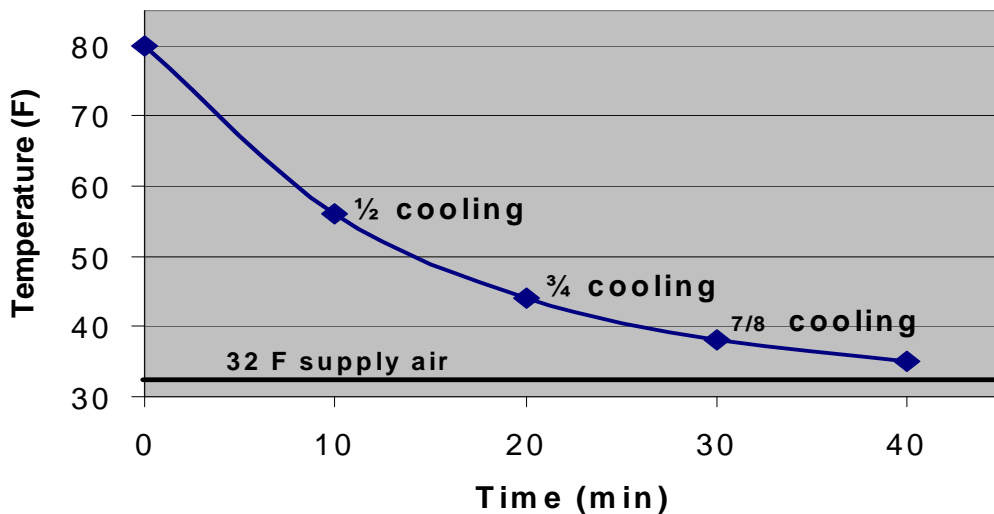
Once packed, cut flowers are difficult to cool. Their high rate of respiration and the high temperatures of most greenhouses and packing areas result in heat build-up in packed flower containers unless measures are taken to ensure temperature reduction. It is therefore necessary to cool the flowers as soon as possible after packing. Forced-air cooling of boxes with end holes or closeable flaps is the most common and effective method for pre-cooling cut flowers. In forced-air cooling, refrigerated air is sucked or blown through a packed box of flowers to reduce their temperature quickly. Most flowers can be cooled to recommended temperatures in 45



min to an hour, and some cut flowers can be cooled in as few as 8 min. For small volumes of packed flowers, this is done by stacking boxes around a fan inside an existing cooler. In larger systems, many fans are permanently mounted against a wall, and pallets or cartloads of flower boxes are positioned next to the fans. The refrigeration system needs to be carefully designed and sized for forced-air cooling.

#### Cooling Time Calculations

The time necessary to reach a desired temperature is expressed in terms of a typical cooling curve. The seven-eighths cooling time, or the time required to reduce the temperature of the flowers seven-eighths of the way from the initial temperature to the temperature of the cooling air, is considered the target for a commercial cooler. This relationship is exemplified in the following figure. Note that the rate of cooling becomes very slow as the temperature of the flowers nears the temperature of the refrigerated air. Consequently, flowers are seldom completely cooled to the temperature of the cooling air. In the flowers being cooled depicted in this figure, half an hour of cooling is required to reach 37.5 F (seven-eighths cooling). More than 2 hours cooling would be required for the flowers to approach the temperature of the cooling air (32 F).



*Cooling curve for cut flowers in a forced air cooler with supply air at 32 F. The half-cooling time for these flowers is 10 minutes*

Care must be taken to pack in such a way that air can flow through the box and not be blocked by the packing material. In general, packers use less paper when packing flowers for pre-cooling. The half-cooling time for forced-air cooling ranges from 10 to 40 minutes, depending on product and packaging. Flowers should be cooled for three half-cooling times (by which time they are 7/8 cool).

Fans

Forced-air coolers use squirrel cage (centrifugal) or propeller (axial flow) fans. Centrifugal fans are much quieter than axial flow fans and can move air against higher static pressures, but may require greater horsepower to operate. Fans are selected based on two criteria – the required airflow, measured in cubic feet per minute (cfm), and the required static pressure, measured in inches of water. The specific requirements are determined by the type of flower, the number of boxes, and venting of the boxes, and the rate of cooling desired.

The airflows and pressures needed to cool a full-sized ‘California’ box of different types of flowers are depicted in the following table. In designing a pre-cooler, the airflow (cfm) required can be estimated by multiplying the required cfm per box by the number of boxes that will be cooled, and adding 25% to allow for air leaks. The number of boxes to be cooled should be based on the maximum number handled on a peak day (such as the period just before a holiday). It is not advisable to use higher airflows than those listed in the table. They will not significantly increase the cooling rate, and will require excessive amounts of energy. The pressure drop for the system is equal to the pressure drop across one box plus 25 percent additional pressure as a safety factor. Do not attempt to cool boxes stacked end to end.

Forced-air cooling: static pressures, airflows, and cooling times required to cool standard boxes of specific flowers

----- Static pressure -----

Flower type*	0.5 inch		1.0 inch		
	Airflow	7/8 cooling time	Airflow	7/8 cooling time	
	Cfm/box	Minutes	Cfm/box	Minutes	
Carnations	70	48	90	40	2
Chrysanthemums	80	62	130	58	2
Gypsophila	170	10	260	8	-
Roses	140	34	200	25	2
Statice	150	40	210	18	2

\*Carnation box size 48x21x12 inches, with two 2-inch diameter vent holes in each end, 51 lb gross weight

\*Chrysanthemum box size 57x21x12 inches with two 2-inch diameter vent holes in each end, and 33 lb gross weight; 45-lb box will allow 50% less air through the box.

\*Gypsophila box size 42x.21x12 inches with two 3-inch diameter vent holes in each end

\*Rose box size 48x21x12 inches, with two 2-inch diameter vent holes in each end, 20 bunches per box.

\*Statice box size 42x.21x12 inches with two 3-inch diameter vent holes in each end and gross weight of 75 lb.

If the packages are to remain in a cool environment after pre-cooling, vents may be left open to assist removal of the heat of respiration. Flowers that are to be transported at ambient temperatures can be packed in polyethylene caskets, foam-sprayed boxes or boxes with the vents resealed. Ice that is used after pre-cooling



is only effective if it is placed so that it intercepts heat entering the carton (i.e. it must surround the product), and care must be taken to ensure that the ice does not melt onto the flowers or cause freezing damage.

### Tropical flowers

Special care needs to be taken with tropical flowers shipped in a mixed load. The flowers should be packed in plenty of insulating material (an insulated box packed with shredded newsprint, for example). These flowers should not be pre-cooled. If they are to be shipped by refrigerated truck, they should be placed in the middle of the load, away from direct exposure to cooling air. Tropical flowers are well suited to air transport, since they are usually of high value, and are damaged by low temperatures.

### Cooling for aquapacks

A marked trend in recent years has been to pack flowers vertically in boxes (Proconas™, aquapacks) that have water (hopefully containing a least a biocide) in the bottom. Considerations of weight and the potential for spills mean that when such boxes are used for air transport, they are packed without addition of solution (which may be added after transport). Pre-cooling of these boxes represents a particular challenge. Palletized Proconas™ can be placed against a modified plenum designed to draw air down through the flowers and out of the ventilation grids and handholds in the hamper bottoms. Padding above the air gap in the plenum seals air from the bottom of the boxes and the pallet. A strip of canvas or sheet of fibreboard around the bottom of the boxes and the pallet ensures that air is drawn down through the boxes.

### Vacuum cooling

While research documenting the use of vacuum precooling for floral crops dates back to the 1950s, few such systems have been used commercially. More recently, however, vacuum coolers have been installed in flower marketing terminals (mostly near airports but also by a few growers) as a means of removing heat from packed flowers.

Vacuum cooling is based on the fact that water boils at lower temperatures at lower pressures. At about 1/10th atmosphere pressure, water boils at 0°C (32°F). When flowers or plants are placed at these low pressures, the water in their cells 'boils', removing heat. Although these systems cool leaves, stems, and growing media promptly and efficiently, flower petals often cool somewhat more slowly, because water cannot escape readily from them. Essentially the same seven eighths precooling time (or possibly 10-15 minutes less) is required to vacuum cool flowers as for the forced-air cooling systems.

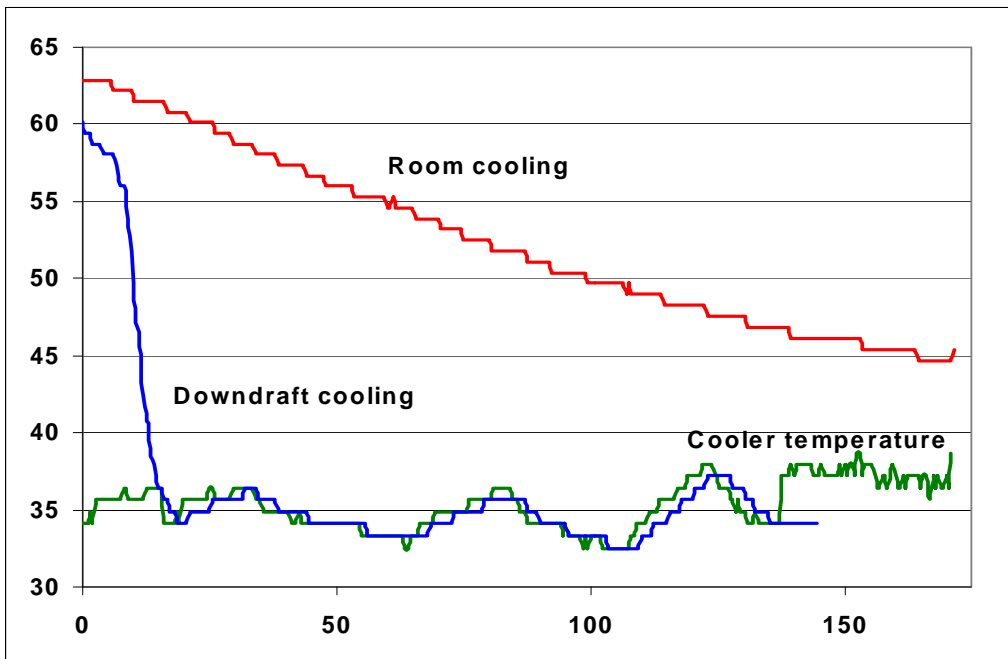
When used at or near airports, these systems serve as a useful 'backstop' for flowers that have not been properly cooled by growers and/or shippers. However, in some cases it can be many hours before packed flowers arrive at the airport or trucking dock, which suggests that they may have already deteriorated significantly before being placed in a vacuum cooler. Some advantages of vacuum cooling methods include that

paper and plastic packaging materials in the boxes do not affect the efficiency of cooling, free water is removed, boxes can be stacked in any manner in the pre-cooler, and it can work equally well with dry packs and wet packs for cut flowers and greens and for potted plants. The main disadvantage is the high capital cost of the equipment. In a centralized facility this high cost can be offset by the high throughput of boxes that these systems can achieve.



*Pre-cooling Procona boxes on a conventional horizontal pre-cooler is achieved by directing the airflow down through the boxes using an adapter plenum, and a fiberboard or fabric sleeve around the base of the boxes.*

This system works very efficiently, and flowers are cooled with a half-cooling time of only a few minutes.



### *Irradiation*

Flowers that are shipped across international or even state boundaries are often subject to quarantine inspection for the presence of harmful diseases and pests. For many years it has been suggested that ionizing irradiation might be used to sterilize or kill insect pests without damaging the flowers. Some proponents of irradiation have even suggested that the irradiation treatment may improve the life of the flowers. The nature of ionizing radiation is such that it leaves no residue after treatment, and if insects could be controlled without any effect on flowers or foliage this would provide an excellent quarantine treatment. Insects are relatively more susceptible to ionizing radiation than plants. Doses as low as 0.2 Gy are sufficient to sterilize most harmful insects. Although flowers do not suffer immediate and obvious damage at radiation doses below 0.7 - 1 Gy, the limited research that has so far been carried out that effects on flower quality and vase life can be detected at radiation doses close to those required to control insects. For example, at 0.2 Gy, vase life of irradiated wax flowers was more than halved. These data indicate the need for careful evaluation of effects on a range of flower species before the adoption of radiation as a measure for insect disinfestation in ornamentals.

## V. QUALITY CONTROL

There are few official grade standards for cut flowers. Some marketing channels, for example the British mass market chains and the Dutch auctions, have internal quality control systems that provide a check on quality of flowers. The most important quality parameter is "freshness" or vase life. This parameter is difficult to assess visually, but because of its importance, producers and receivers should set up a "quality control" program that would involve evaluation of the vase life of representative flowers on a continuing basis. Such a program would answer questions such as:

- Have these flowers been properly treated with STS or 1-MCP?
- Will these flowers have a reasonable vase life?
- Are credit claims justified?
- Does the pulse pretreatment improve flower quality?

Such a program might involve one employee for no more than 20 minutes per day, and would repay dividends in terms of information about the products handled and the effects of any pretreatments applied.



Overpacking boxes results in crushing of petals, misalignment of pre-cooling vents, ineffective precooling, and poor stacking. Note that the bunches should be placed at least 5 cm from the end of the box to allow cool air to flow through all the flowers.

## VI. Logistics for air transport of cut flowers

Because of the dramatic effects of transport temperatures on subsequent vase life and the propensity for overheating of packed flowers, they should be transported at close to the optimal temperature (0°C for most species). Some systems already exist for aircraft transportation of flowers under controlled temperatures. Elsewhere in this manual, passive and active refrigeration systems are described that could usefully be applied to the transportation of cut flowers. Envirotainers™, as an example, provide a dry-ice refrigeration system that could provide controlled temperatures suitable for use with cut flowers and would allow transport for a considerable distance at costs that would be more than recompensed by the improved quality of the flowers on arrival. Passively refrigerated and insulated containers provide alternative means for providing some control of temperature during transport. If product is properly cooled before being palletized or packed in an LD-3 container, insulation alone certainly will improve temperature management during the transportation chain. Given the lack of temperature control in the majority of aircraft carrying cut flowers, and the extreme response of cut flowers to temperature abuse, the logistics for air transport of cut flowers must focus on doing everything possible to maintain the cold chain. Flowers should be properly cooled at the grower's operation, and transported to the airport in refrigerated (or at least well insulated) trucks. In some airports vacuum coolers that been installed to reduce temperature of flowers before they are air-freighted. This expensive equipment certainly provides a means of rescuing product that is warm on arrival at the airport, but this is not an optimal procedure. Prior heat exposure and the additional water loss from the flowers during the vacuum cooling process undoubtedly compromise flower quality and vase life.

Perhaps the weakest link in the flower postharvest chain is at the airport. Freight forwarders may be inundated with late arrivals just prior to aircraft leaving. Pallets are assembled hastily, there is no time for pre-cooling of warm flowers, and boxes are handled roughly. Pallets may be at ambient temperature for up to 4 hours while the aircraft is being loaded. The producing and transportation industries need to work

together to set standards for temperature management, pallet construction, and temperature maintenance during loading.

#### *Temperature management before loading*

Ideally, flowers would be packed and cooled at the production location and loaded into LD-3 containers or made into pallets on LD-9 sheets before being transported in a refrigerated vehicle to the freight forwarder or air cargo facility. Whenever active refrigeration is not available, flowers should be kept cold by the following measures:

- Consolidation into pallets to reduce the surface/volume ratio
- Reduction in radiative heat gain by holding in a shaded location
- Reduction of air infiltration by closing precooling vents (essential), and using pallet covers. Pallet covers should preferably be white or foil backed, and have the additional benefit of reducing water loss during air transport.

Flowers cooled to 0°C and packed in a large pallet will gain about 1°C per hour due to the heat generated by the process of respiration. As the temperature rises, respiration rises, and the heat gain increases too, so that by the time the flowers are at 10°C they may gain 3°C per hour, and once they are at 20°C, the heat gain can be as much as 10°C per hour. Flower boxes unloaded from aircraft pallets have been probed at temperatures as high as 55°C, indicating the runaway danger of inadequate temperature management and delays in transport.

#### *Pallet construction*

Flowers are delicate, and box strength is compromised if corners don't line up. It's important that the pallet be constructed so that the corners are square and line up above each other. One of the most vexing problems of the flower industry is the wide array of box sizes, which may make construction of a square and well aligned pallet difficult. Walking or kneeling on flower boxes should not be permitted. If it's necessary to provide trestles and planks to allow construction of pallets without workers kneeling or walking on the boxes, that would be money well spent. Preferably, the pallets should be constructed from the side (base to top for each successive layer. Standardization of boxes so that they easily fit the standard LD-9 and LD-3 footprint would help a good deal. Immediately after pallet construction, the palletized flowers should be covered with an insulated cover (or at least with shrink- or cling-wrap polyethylene film. This will reduce heat gain as a result of air movement through the pallet.

## VII. USEFUL REFERENCES AND SUGGESTED FURTHER READING

Berkholst, C.E.M., et al. 1986. Snijbloemen. Kwaliteitsbehoud in de afzetketen. Sprenger Instituut, Wageningen. 222 pp.

Carow, B . 1981. Frischhalten von Schnittblumen. Verlag Eugen Ulmer, Stuttgart. 144 pp.

Halevy, A.H. and S. Mayak. 1979. Senescence and postharvest physiology of cut flowers, Part 1. Horticultural Reviews, 1:204-236.

Halevy, A.H. and S. Mayak. 1982. Senescence and postharvest physiology of cut flowers, Part 2. Horticultural Reviews, 3:59-143.

Hardenburg, R.E., Watada, A.E., Wang, C.Y., 1986. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. USDA Agriculture Handbook 66., 130 pp.

Larson, R. A. (ed.). 1980. Introduction to Floriculture. Academic Press, Inc., New York, New York. 607 pp.

Lutz, J. M. and R. E. Hardenburg. 1968. The commercial storage of fruits, vegetables, and florist and nursery stocks. U. S. Department of Agriculture. Handbook No. 66. 94 pp.

Mayak, S. and A.H. Halevy. 1980. Flower Senescence. IN: (ed. K.V. Thimann) Senescence in Plants, CRC Press, Boca Raton Fl., pp. 131-156.

Nowak, J., and R.M. Rudnicki. 1990. Postharvest handling and storage of cut flowers, florist greens, and potted plants. Tiber Press, Portland, OR., 210 pp.

Rij, R.E, Thompson, J.F., and Farnham, D.S. 1979. Handling, pre-cooling and temperature management of cut flower crops for truck transportation. USDA AAT-W-5/June 1979 26 pp.

Sacalis, J.N. 1989. Fresh (cut) flowers for designs. Postproduction guide I. D.C. Kiplinger Chair in Floriculture, Ohio State University. 128 pp.

Staby, G. L., J. L. Robertson, D. C. Kiplinger and C. A. Conover. 1976. Proc. of National Floricultural Conference on Commodity Handling. Ohio Flor. Assoc., Columbus, Ohio. 71 pp.

Thompson, J.F. Mitchell, F.G., Rumsey, T.R., Kasmire, R.F., and Crisosto, C.H. 2003. Commercial Cooling of Fruits, Vegetables and Flowers, Revised Edition, University of California, ANR publication #21567, 59 pp.

Thompson, J.F., Bishop, C.F.H., and Brecht, P.E.Patrick. 2004. Air Transport of Perishable Products. University of California ANR publication #21618. 22 pp.

## VIII. GLOSSARY

abscise	- fall off, as of a leaf or petal falling off the flower
adjuvants	- additives, as chemicals added to a preservative to enhance its effectiveness
anthocyanins	- blue and red coloured pigments in plants
ambient	- normal room temperature
axil	- the junction between a leaf and a stem
biocide	- chemical killing microbes
bracts	- leaf-like structures (normally green) at the base of an inflorescence.
bullheads	- oversized buds, normally having more petals than normal
cultivars	- botanical name for horticultural varieties
desiccation	- drying out
disbuds	- flowers that have had side-buds removed
gibberellic acid	- growth regulator causing stem elongation in plants
inflorescence	- flower comprised of many florets
margin	- edge of a leaf or petal
necrosis	- death and drying of a leaf or petal, often in small localized regions
osmotic pressure solution.	- pressure exerted by the water-absorbing property of a solution.
panicle	- a compound inflorescence
spike	- long inflorescence having multiple florets
turgidity	- resistance to deformation of a water-containing tissue

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