POST-HARVEST FACTORS AFFECTING CUT-FLOWER LIFE*

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The emphasis in floriculture has long been on producing flowers, with little effort to learn to handle them after they have been produced. Yet, most flowers are among our most perishable crops, often becoming worthless within a couple of days unless properly handled. Fortunately, this situation is beginning to change. Increasing attention is being given to research in post-harvest floriculture, and in this report I shall review current thinking on flower handling as best I can determine it from the literature and from our own observations. Since the use of chemicals was reviewed in a previous article (MFGA Bulletin 109, November 1968), only environmental controls will be considered here.

In examining ways to extend flower life, it is important to first understand why flowers deteriorate so quickly. The main reasons are these: desiccation, starvation, disease, old age, and discoloration.

Desiccation, or drying-up, obviously occurs quickly when flowers are left lying or setting dry. They have much surface area from which to lose water. But desiccation is not restricted to flowers out of water. Even when standing in water, they often wilt due to the plugging or deterioration of their vascular systems. Desiccation is clearly a major cause of flower deterioration.

Starvation is another important factor. Unlike fruits and vegetables, flowers usually have very little food reserve when harvested. Furthermore, they are often growing and developing rapidly after harvest, and their available food is rapidly exhausted. Unless fed by some means, the flowers will then die.

Diseases, especially *Botrytis* rot or gray mold, often attack flower petals and ruin the blooms. This problem is accentuated when flowers are stored or packed in polyethylene films. Inside these films, humidity is usually very high and the fungi flourish.

Senescence, or old age, develops rapidly in flower petals, but for some unknown reason cutting a flower accelerates the process. Cut flowers age faster than attached flowers even when held under identical conditions. A factor involved in aging is pollination. It is known that at least for lilies and orchids, removal of stamens before they are mature (thereby preventing pollination) will add to the life of the blooms.

Discoloration of petals sometimes ruins blossoms. A good example of this is 'Better Times' roses which develop a blue color with aging, due to biochemical changes in the petals. There are a number of other causes of discoloration besides aging; for example, exposure to ammonia gas causes blueing, as does too high a CO_2 level in the atmosphere. Starvation, too, can cause discoloring. A good example is when pink snapdragons produce very pale or white florets at the lower end of a cut spike. For the pink color to be formed, ample sugar is needed. In a starving plant the sugar is lacking, and as a result the color is lacking.

These are the major known causes of flower deterioration, and all of them are influenced by the environment the flowers are exposed to after harvest. Therefore, proper

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control of the environment is essential to get the most out of post-harvest life of flowers.

Undoubtedly, the most important factor to be controlled is temperature. Temperature controls the rates of all the chemical and physiological processes occurring in the flowers, and it is the keystone in all that is done to flowers after harvest. Life of many flowers can be stretched from a few hours into several days, weeks, or even months simply by manipulating the temperature around them.

What temperature is needed? That depends on what you are doing with them, and to some extent on the kinds of flowers with which you are dealing. For display purposes, flowers will stay fresh progressively longer as you lower the temperature. The consumer usually displays flowers at least at 70° F, and this ensures that they will die quickly. Under these conditions, maximum life will be obtained by using freshly cut blooms of proper maturity, and by not exposing them to any higher temperature or for any longer period than is necessary.

If flowers are not going to be used immediately, refrigeration should be employed with the objective to *lose* as little flower life as possible. Cold storage will never *add* anything to flower display life, it will merely reduce loss of life before display. Therefore, for storage we want to slow down change as much as possible, so we should use as low a temperature as possible and that is usually 31-32° F. The effects of temperature during storage are illustrated in Table 1. Storage at 45° for up to 6 days produced no detectable loss of life, but extending storage to 10 days caused a loss of 2 days in display life. In contrast, flowers at 35° were stored for 10 days without loss of display life. For storing only a few days, you can seldom see a difference between flowers held at 32° and ones held near 50°, however, if the flowers are not used in a few days, the higher temperature will have taken a high toll in display life.

TABLE 1
Display life (in days) of narcissus blooms at 60° F following storage.

Storage temp. (°F)	Days in Storage 0	2	4	6	10	15
60°	7.6	...	...	...	...	...
45°	...	7.1	7.3	7.6	5.3	3.0
35°	...	7.4	7.7	7.6	7.2	6.3
2 days 65° then 35°	...	2.9	3.1	3.4	2.0	2.0

From: Smith and Wallis. 1967. Exp. Hort. 17:21-26.

Another point illustrated in Table 1 is the effect of delay in refrigeration. Blossoms held 2 days at 65° and then placed at 35° had little display life after storage. If flowers are permitted to deteriorate at high temperature, there is little use in subsequently storing them. Storage will not breathe new life into them.

The importance of refrigeration—as quickly as possible and at the proper temperature—at all stages of handling flowers cannot be overemphasized. One area where losses frequently occur is in shipping, where refrigeration is often lacking or inadequate. The effect of this is seen in Table 2. Carnation buds lost 2 days of display life during the first day or 2 of simulated shipping, but lost half their life (8 days) if shipping time was extended to 3 days. Open blooms were affected even more harshly. Three days of shipping virtually destroyed them.

TABLE 2.
Display life (in days at 63° F) of carnations after simulated shipment at 75° F.

Hours at 75°	Buds	Open blooms
0	16.0	16.1
24	13.8	15.3
48	14.2	13.0
72	8.3	2.2

From: Holley and Cheng. 1967. Proc. Amer. Soc. Hort. Sci. 90:377-383.

How cold can flowers be kept? An obvious lower limit is where they will freeze, and that is about 30° F. Storage of most flowers is recommended at 31-32° to obtain maximum post-storage life. However, there are some flowers that will be injured by temperatures well above the freezing point. This "chilling injury" usually causes petal injury, and results in recommendations for storage of numerous flowers (e.g., orchids, camellias, gladioli, gardenias, anthuria) at temperatures well above 32°. However, we have looked for chilling injury in many of these flowers and have obtained clear symptoms on only Cattleya orchids and anthuria, and then only after 4-10 days at 34°. I believe that with few exceptions you should be storing flowers as close to 31-32° as possible. If unusual petal injury is found, however, the possibility of chilling injury should be investigated. Knowledge about chilling injury to flowers is extremely limited, and you may have to do some investigation yourself.

While temperature is the key environmental factor in post-harvest floriculture, it is by no means the only one. Humidity is also very important. If relative humidity is low, flowers will give off large amounts of water. If they are in water and their vascular systems are working properly, this will be no problem, but if they are not in water or their vascular systems are plugged, then

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the lower the humidity the faster they will wilt. The higher the temperature, the more important relative humidity becomes, for at high temperatures air will absorb large quantities of moisture.

For most flower handling, too high a humidity is more of a problem than too low a humidity. The problem here is not wilting but disease. Fungal spores will not grow in a dry atmosphere, so at low humidity few if any fungal infections will occur. However, if the humidity reaches 95-100%, spores will germinate and grow—slowly at low temperature, rapidly at high temperature. This can be a problem during storage, but the most important site of high humidity is in packages. If flowers are packed in polyethylene or similar films, high humidity will quickly develop *even if the pack is ventilated.* And if warm flowers are packed in film and the packs are then placed into a cooler, condensation will almost certainly occur in the packs. This means 100% humidity and means diseased flowers within a very short time. Flowers should not be packed in film unless they can be sold and/or unpacked within 24 hours.

A third environmental factor that can affect post-harvest life is light. Green plants photosynthesize (make food) in light, and even after harvest there is usually plenty of green tissue attached to the blossom. This tissue can photosynthesize and ward off starvation if illuminated. Furthermore, the red pigments in most flowers require light for synthesis; therefore, florets opening in darkness may be discolored. Whenever possible, flowers should be stored in light. Results from a study on the benefit from light are shown in Table 3. At 45°, light added 4 days to the life of chrysanthemum flowers, and at 75° 7 days were added. Lighting can substantially add to flower life.

A fourth environmental factor to be considered is atmospheric composition. Air usually consists of about 79% N_2 and 21% 0_2, with a fraction of a per cent of CO_2 included. It has been demonstrated conclusively that for apples and pears, modifying this composition (e.g., 3% O_2, 5% CO_2, and 92% N_2) will greatly increase storage life. Commercially, this is controlled-atmosphere (CA) storage. Can CA be applied to flowers with similar benefit? A number of researchers have pursued this question, and results of their tests have not been encouraging. In most tests, consistent benefits have not been found, and often it has been shown that if O_2 gets too low the flowers will ferment, and if CO_2 gets too high a variety of injuries result, but in particular red flowers will turn blue or purple. (This blueing is reversible, and if a grower discovers that blueing has occurred during storage he should put the flowers in open air for a day. If high CO_2 is the cause, they should return to normal color). Prospects are not good for CA storage of flowers, but more research is needed on this method. Not all experiments have been discouraging. For example, in Table 4 are shown results of an experiment conducted with daffodils. These flowers did not ferment in 100% N_2, and exhibited twice the display life of similar blooms stored in air. These findings indicate that there may be some future for CA storage of flowers, but that future almost surely would be limited to certain kinds of flowers.

TABLE 3

Life (in days) of chrysanthemum blooms.

Storage temperature	Stored in light	Stored in dark
45° F	37	33
75° F	20	13

From: Woltz and Waters. 1967. Proc. Amer. Soc. Hort. Sci. 91:633-644.

TABLE 4

Display life (in hours at 72-74° F) of daffodils following storage.

Days in storage	Stored in air	Stored in 100% N_2
14	56	108
21	40	90
25	30	78

From: Parsons, Asen, and Stuart. 1967. Proc. Amer. Soc. Hort. Sci. 90:506-514.

It should be clear that by controlling the environment around cut flowers much can be done to reduce the rate of their deterioration.

What then are the recommended storage and handling procedures? First and foremost, control flower temperature. Unless flowers can be cooled right after cutting and kept cold until they reach the consumer, much of their life will be lost quickly. If flowers are held only briefly—1-2 days at the most—exact temperature control is not critical. However, a temperature of 32° F will protect you if you should have to hold flowers longer than anticipated. In regard to chilling injury, I doubt that serious danger exists during several days at low temperatures except possibly for a few flowers like Cattleya orchids and anthurium blossoms. However, you should be alert for unusual injury, especially to the petals, at low temperatures. I would recommend keeping the storage area lighted, though short-term benefits would be small unless the temperature is high.

For long-term storage, precise temperature control is very important. Non-chilling flowers should be held as close to 31-32° as is possible for maximum benefit from refrigeration. Lighting the storage is recommended if the flowers have not been pre-packaged. For long-term storage, it is recommended that flowers be stored dry rather than in water. A slightly wilted condition seems to reduce aging at low temperatures, and it has been shown repeatedly that dry-stored flowers have a longer display-life than ones stored in water. If flowers are dry-stored, it then becomes critical that humidity be carefully controlled around them. To prevent excess wilting, 90-95% RH is essential. Of course, humidity above 95% will promote fungus growth.

For flowers that have been dry-stored, a "hardening" treatment is very important when they come out of storage. This treatment consists of cutting of about ½" of stem (since the end is often crushed or plugged) and placing the stems in warm water (110° F) but in a cold room (40° F) for 24 hours. The objective of the treatment is to make the slightly wilted flowers turgid again, through promotion of water uptake with the fresh-cut stems in warm water, and at the same time

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minimizing evaporation by placing them in cold air. Hardening should revive flowers completely unless they have been allowed to wilt too much due to too low a humidity in the storage.

Except for the need to harden dry-stored flowers, handling of stored flowers is no different from handling of fresh flowers. They should be handled carefully, kept as cold as possible, protected from both wilting and condensation of water, and sold as quickly as possible.

It must be remembered that the freshly-cut flower has the maximum post-harvest life. The objective of post-harvest handling should be to lose as little of that life as possible before the flower reaches the consumer. There is nothing you can do to add to the life of the fresh-cut bloom, but there are many ways to reduce the rate of loss of this life. The more life there is in the flowers that reach the consumer, the longer she will be able to enjoy the flowers and the more likely she is to return for more of this beauty.