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Postharvest management of new potential cut flowers

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ABSTRACT

Among agricultural businesses, the ornamental industry emerged as a key component of our economy with a strong market position and promising aspects. The appetite to explore new things is crucial to the growth of the marketing industry. It is long overdue for the floriculture sector to switch to new crops in light of current trends and the ongoing demand for fresh, inventive goods. The most significant concern, however, is the poor after-harvest outcomes of cut flower crops including poor handling, harvesting injuries, poor flower quality, market glut, which have decreased demand for fresh-cut flowers. Thus, every link in the marketing chain must provide sufficient postharvest care. 'Freshness' and vase life are the two crucial qualities depending on the best postharvest management. The grower must be ready to modify production to satisfy customer preferences to achieve successful long-term benefits. The purpose of this review is to highlight some new special flowers postharvest strategies depicting their capability of introduction with traditional cut flowers.

Keywords: *Floriculture, Post-harvest, Potential flowers, Vase life, Stages, Ethylene, Senescence*

INTRODUCTION

Floriculture is an emerging sector contributing to countries' social, ecological as well as economic growth. However, the quality maintenance of these products is a challenging task, especially with a foremost condition to satisfy consumer demands. The florists and consumers are always in need of something new and beneficial and with the introduction of new potential cut flowers one can put to use the represented variability among themselves. People prefer fresh & fragrant flowers for occasional purposes such as marriage, birthdays, anniversaries, farewell ceremonies, etc.

Since cut flower longevity is the only required factor influencing buying choices, as less the flower life lesser its reputed demand [16]. Lack of expertise regarding the post-harvest care of the new potential cut flowers mandates a search for effective and doable methods for flower growers, wholesalers, and retailers to improve quality and presentability. The various improved post-harvest operations are the key to satisfying and meeting customer preferences. The flower's presentability is mostly dependent upon its growing conditions, harvest timing, transportation facility, and postharvest handling which further results in high quality, less transpiration losses & maintain turgidity. In this review article postharvest studies of different new potential cut flowers like Baby's breath (*Gypsophilla paniculata*), China aster (*Callistephus chinensis*), Delphinium (*Delphinium elatum*), Floss flower (*Ageratum houstonianum*), Godetia (*Clarkia amoena*), Kangaroo paw (*Anigozanthos spp.*), Lisianthus (*Eustoma grandiflorum*), Lupine (*Lupinus havardii*), Peony (*Peonia cvs.*), Snapdragon (*Antirrhinum majus*), Statice (*Limonium sinuatum*), Stock (*Matthiola incana*), Sweet pea (*Lathyrus odoratus*), Fressia (*Freesia refracta*), Hydrangea (*Hydrangea macrophylla*) etc. will be discussed.

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GLOBAL SCENARIO OF CUT FLOWERS

In the past 20 years, cut flower production and consumption have overcome significant obstacles, particularly those inflicted by worldwide financial crises (Average yearly growth of 6% to 9%). For the past 200 years, the Netherlands (52% of global production as of 2018) has been regarded as the heart of global trade regarding cut flowers. The auction house at Aalsmeer is still regarded as a crucial part of import and export purposes [4]. Many new cut flowers with novelty in colors are being traded around the year, during peak seasons as well as off seasons. The cut flower market reveals a share of traditional and seasonal flowers and foliage which are majorly cultivated via contract farming and on demand basis. The market value size in 2022 is USD 36.4 billion and it is projected to be worth USD 45.4 billion by 2027. [13] stated that many new potential cut flowers could bring in $ 25,000 - $ 35,000 per ha on an annual basis.

INDIAN SCENARIO OF CUT FLOWERS

India has gained momentum in the floriculture sector with positive incremental results obtained since the 1990s. The net worth of India's Floriculture market is INR 231.7 billion in 2022 and is further projected to be INR 460.6 billion by 2028 [56]). According to APEDA, the total area under cultivation of flowers is 283 (000' ha) with a production of around 2295.07 (000' tons) of loose flowers and 833.16 (000' tons) of cut flowers in 2021-22. Nowadays, the Indian cut flowers plants list has been extended to some new flowers namely Delphinium (blue, pink, purple) with year production potential, Hydrangea, Freesia, and a list of few fillers including, Statice & Gypsophila flowers [42].

SCOPE OF THE REVIEW

Among various ornamental cut flowers, maximum interest has

already been occupied by main crops like roses, carnations, gerbera, lilies, chrysanthemums, etc. Since flowers are regarded as a better alternative for natural beautification with seasonal variations, it is essential to introduce new specialty flowers. Moreover, Indian climatic conditions are best suited to shift attention toward some new potential cut flowers that emerged with better vase life with enhanced beauty, fragrance, and distinct colors. Keeping in view the importance of postharvest management of new cut flowers in the international market, this article covers the compilation of postharvest studies of new potential cut flowers.

The operations performed after harvesting of flowers which helps in maintaining and enhancing their quality and aid in retaining freshness for longer duration is defined as post-harvesting. The producer will fetch the value of a flower only after being sold and a purchaser expects a product that lasts well. The longevity of a flower along with long-lasting freshness will make a floriculture product worthy of consumer satisfaction. The physiological approaches after harvesting or plucking of flowers assist the gardener in taking postharvest operations in step step-wise manner. The caring considerations vary from flower to flower either physiologically or genetically.

Post-harvest losses in a cut flower begin from the field and continue till their life termination by following reasons as mentioned below:

1. Depletion of CHO
2. Water loss
3. Stem blockage
4. Air blockage
5. Ageing and Senescence
6. Rotting of stems and flowers
7. Mechanical injury

Therefore. it is very important to study the post-harvest physiology of a cut flower. There are two distinct phases in a cut flower life cycle bud development to bud opening and blooming to senescence. After the detachment of inflorescence from the mother plant, various physiological processes take place such as increased respiration, more transpiration loss, fast water uptake, and release of ethylene. All metabolic processes are interrelated. A flower's longevity is determined by the rate of transpiration through the stomata opening. Likewise, enhanced respiration rate is linked to more transpiration losses and finally, rapid senescence of cut flowers [18]. in crops such as godetia, freesia, delphinium, etc.

Since, the petal's developmental stages are characterized based on cell differentiation, cell enlargement, cell division, and later death, which includes wilting and fading of flowers [61]. This process leading to plant death is a degradative process, also called senescence. This process is generally associated with various physiological and biochemical changes that occur during a flower's complete life cycle duration. Water loss from senesced tissues, ions leakage, enhanced membrane fluidity, and hydrolysis of carbohydrates, proteins, and nucleic acid [26].

Moreover, when ethylene production is inhibited chemically or genetically, the onset of flower senescence is delayed in many dicotyledonous flowers whose senescence is dependent on ethylene action. However, many monocotyledonous flowers' senescence is assumed to be predominantly regulated by ABA and is largely ethylene-independent [36].

This is mainly associated with the degree of sensitivity of flowers which differs among different species and cultivars [49].

There are several factors which affect the post-harvest life of a cut flower:

Temperature: Post-harvest life of flowers mostly depends upon temperature availability and respiration rate as they are interrelated. The rise in ambient temperature increases respiration rate and vice-versa. The aftereffects can lead to fast aging, increased senescence, and reduced life cycle. The flower's exposure to warm temperatures exhibits bent stems, loss of lower florets, and incomplete opening of flower buds. Even the use of preservatives will be altered and disturbed, under hot temperatures. The abscission of delphinium sepals was found to accelerate as flowers ages whereas, reduced ethylene sensitivity was found in early time of anthesis [29].

Ethylene: The majority of cut flowers are sensitive to ethylene, even a slight exposure brought detrimental effects on them. For instance, in sweet peas, ethylene involves the death of flowers, however, in others like delphinium, and snapdragon, it results in abscission/shattering. The old decaying plant parts, injured or mechanically damaged plant parts also release ethylene. Exposure of delphinium sepals to 10 µL/L ethylene concentration had no effect during the first 24 hours. However, continuous accelerated ethylene application for 1 to 2 days had significantly led to sepal abscission. Pollination has been found to cause a spike in the ethylene biosynthesis enzymes S-adenosyl-methionine (SAM) synthase, ACC synthase, and ACC oxidase in species exhibiting ethylene-sensitive floral senescence [51]. Its production is generally related to pollen tube stretch in style and then with fertilization, resulting in autocatalytic production of ethylene in petals [24].

Ethylene damage is characterized by premature petal wilting, petal abscission, and rapid senescence of floral organs, greatly shortening the postharvest life of the flowers. Even at a very low concentration of ethylene (< 1 ppm), it is injurious to many cut flowers [46**;** 48]. While others cut flowers like delphiniums and snapdragons senesce early when exposed to exogenous ethylene. Here are some names of flowers distinguished on ethylene sensitivity basis like Delphinium [17], godetia [5], gypsophila [17], lisianthus [45], snapdragon [17], stock [45], sweetpea [35] and some insensitive flowers are ageratum, Paeonia [63], statice [22], kangaroo paw [60] and china aster.

Water quality: The cut flowers' longevity is significantly affected by water quality. Higher alkalinity of tap water will prevent the availability of an ideal pH range (3.0-3.5). The low-pH water favors quick absorption by cut stems and diminishes microbial growth. Moreover, the cut stems should be placed in cold water instead of warm water as it will promote a hydro-cooling system. While, species with large leaf surfaces should be watched closely as they transpire fast and water uptake is higher [48]. [59] evaluated the longevity of 14 different cultivars of peony cut flowers treated under normal water, and a range of 7 to 20 days was obtained respectively. The following cut flowers' vase life is depicted below in Table 1.

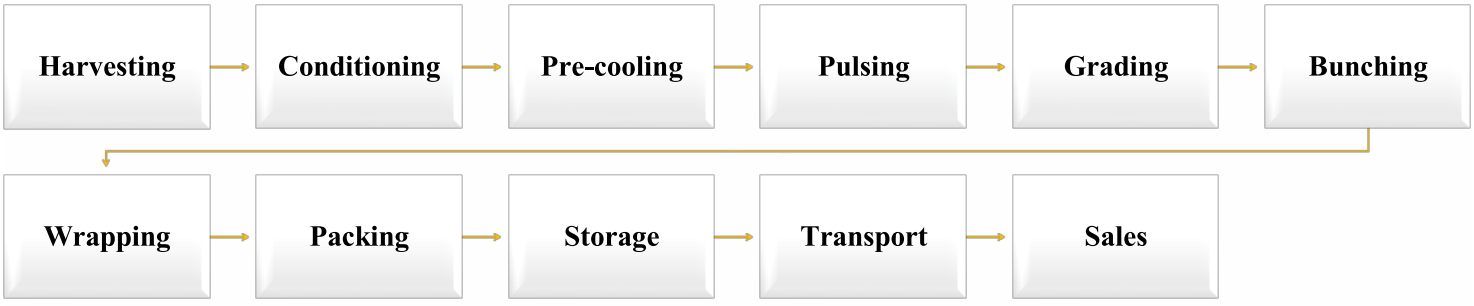
Table 1: Vase life of new potential cut flowers

Flowers	Vase life (days)	References
Ageratum	7-10	[15]
China aster	5-7	[19; 20]
Delphinium	4-12	[33]
Godetia	5-7	[19; 20]
Gypsophila	5-10	[33]
Kangaroo paw	10-15	[30]
Lisianthus	8	[19; 20]
Limonium	10-12	[19; 20]
Lupine	5-7	[19; 20]
Peony	2-7	[33]
Snapdragon	5-7	[33]
Stock	5-8	[19; 20]
Sweet pea	3-7	[33]
Freesia	14-21	[42]
Hydrangea	2-3	

6. POST-HARVEST MANAGEMENT:

The series of steps involved from harvesting to marketing of cut flowers to enhance vase life and quality of flowers is depicted in Figure 1. Strategies should be applied to improve and enhance cut flowers' quality and presentability throughout the post-harvest operation cycle. Moreover, appropriate measures are involved which favor reduced damage and proper care of cut flowers.

Figure 1: Steps involved in postharvest management



1. HARVESTING: The flowers are generally harvested by hand by using a sharp knife or secateurs. Ideally, harvesting is done in cool morning or late evening hours and care should be taken to avoid any mechanical injury or damage.

Variations in harvesting time and stage of development (Table 2) had a significant effect on flower vase life. For example, the flowers belonging to the Asteraceae family (Ageratum) are harvested during full maturity but inflorescences including multiple buds will be plucked at half-open stage [6; 21]. [3] evaluated Lisianthus cut flower longevity at different harvesting time intervals i.e. from 0700 hr to 0800 hr and 1700 hr to 1800 hr. The vase life obtained was 10.7 days in the early morning hours whereas, it was increased to 11.2 days when harvested in the evening hours.

Table 2: Harvesting stages of new potential cut flowers

Flower	Harvest stage	References
Ageratum	Flowers just began to open (when two or three florets were tightly opened)	[6; 19; 20]
China aster	When the flowers have just started opening	[19; 20]
Delphinium	When about 70% of the florets one-half florets open	[29]
Godetia	When first bud began to open	[43]
Gypsophilla	60% to 70% flowers fully opened	
Kangaroo paw	When 1-3 florets open	[30]
Lisianthus	Local market- 1-2 flower fully coloured Distant market- First bud showing colour	[6]
Lupine	Local market- Lower 1/3 florets open Distant market- Lower 1-2 florets open	[6]
Peony	Coloured buds	[27]
Protea	When 30% of flowers open	[55]
Statice	Almost fully open flowers	[55]
Snapdragon	When flowers on the lower ½ to ⅔ of the spike are open	[33]
Stock	Local market- 1/3 – ½ of inflorescence open Distant market- Lower 1/4 of inflorescence open	[6]
Sweet pea	One half floret open	[33]

2. Preservatives for improvement in new potential cut flower's longevity

A flower's longevity can be enhanced through the correct application of postharvest material. Various ingredients are as follows:

• **Biocides:** These are used to restrict the growth of microorganisms such as molds, and yeast. These microorganisms multiply rapidly in the water.

After harvesting, the cut stems are placed in water, further, the uptake of water takes place with the help of xylem vessels. However, if xylem vessels get blocked, water transportation stops, and ultimately flowers show a wilting appearance. Stem blockages are more likely to occur due to poor hygiene, significant microbial growth, high-temperature conditions, etc. must be prevented. [59] found the longest peony cut stem life (21.9 days) of the "Graziella" cultivar in a solution comprising 8-HQC (200 mg/L) + Sugar (20 g/L).

• **Sugars:** It is the key component that acts as a food source that energies the flower by providing carbohydrates so that they can complete their life cycle from bud opening stage to flower bloom with better quality and prolonged post-harvest life.

• **Acidifiers:** Acidifiers, like citric acid, are used to improve cut flowers post-harvest life because they facilitate water absorption and help in achieving the acidic pH of the solution, to inhibit the growth of microbes.

• **Ethylene blockers:** Ethylene plays a crucial role in the flower post-harvest cycle. The exceed in ethylene concentration may lead to improper bud opening, shriveling, and bud drop.

Chemicals used for inhibiting ethylene ill effects:

- Amino-ethoxy-vinyl glycine – [29] applied **AVG** @ 10 mM to delphinium cut flowers and bought a significant delay in abscission by inhibiting ethylene release.
- Amino-oxy-acetic acid (AOA)
- Methoxy-vinyl glycine
- Silver thiosulphate (STS), ***but now banned***
- 1-MCP (1- Methyl Cyclo-Propene)- a non-toxic synthetic gas @ 10-20 ppb for 6-12 hours at 20°C. On treatment with 1-MCP @ 20µl/l, flower longevity of stock cut stems enhanced from 2.3 to 5 days, while antirrhinum case life extended from 3.0 to 6.5 days, respectively [53].
- Silver Nitrate ($AgNO_3$)

3. CONDITIONING: Flowers are maintained loosely standing in a large container during the basic process of conditioning or hardening so that air can circulate the stems. Most importantly, the turgidity of cut flowers that have been hampered by water stress during their transport and storage will be restored [10].

4. PRE-COOLING: It is an important operation practiced to remove field heat from the harvested cut flowers and bring down temperature from 25-30° C to 10° C under short duration of time. The beneficial results can be obtained including reduced respiration, transpiration losses, etc [34].

5. PULSING: The process of preparing a chemical solution comprising sugar and germicide in which cut stems are kept for a duration ranging from 2 to 24 hours is defined as pulsing. The main purpose behind this operation is to lengthen the flower vase's life, encourage opening, and fresh appearance, and enhance petal color. The high sucrose concentration is used in pulsing and the percentage varies from flower to flower. The flowers are kept under holding solutions to stand continuously. Holding solutions are helpful in re-hydrating tissues and provide carbohydrate sources till the termination of flower life.

Chemical Used for Pulsing of New Potential Cut Flowers

FLOWER	CHEMICAL SOLUTIONS
Eustoma	1.) 6% sucrose for 24 or 48 hours and then place in distilled water increases flower opening [14]. 2.) 8-hydroxyquinoline sulfate (8-HQS) and 4% sucrose for 24 h at 20ºc improved water uptake and flower opening [29]. 3.) Addition of a 24-h BA pulsing at 20ºC prior to the 24-h sucrose pulsing, promoted even further flower longevity [28].
Lisianthus	10% sucrose for 24 hours [12].
Peony	1.) 20% sucrose for 24 hours provided optimum solution uptake and fresh weight [32]. 2.) 30 minutes pulsing of 1mM STS increased vase life by upto 2.5 days [32].
Protea	Species that are susceptible to leaf blackening may be pre-treated by pulsing overnight at 20 to 25 °C (68 to 77 °F) with 5% sugar (sucrose or glucose) [55].
Statice	10% sugar and 200 ppm Physan-20 for 12 h [48].

Holding Solutions for Different Cut Flowers

Flowers	Chemical solutions	Reference
Delphinium	Sucrose 1% + 8-HQC (200ppm)	[19; 20]
Godetia	8-HQC (200ppm) + 1% sucrose	
Gypsophila	1.) Sucrose 2% + 200ppm 8-HQC 2.) Sucrose 3% +200ppm AL2(SO4)3	
Snapdragon	1.) 300ppm 8-HQC+ 0.5% sucrose 2.) 300ppm 8-HQC + 1.5% sucrose	
Statice	2.5% sucrose + 150 mg/l 8- HQS increased keeping quality in Limonium sinuatum.	[48]

6. GRADING & BUNCHING: This operation is done to prevent contamination of other flowers by discarding damaged and diseased blooms.

- It is done based on size, length, and flower quality.
- Also based on the standards recommended for various annual cut flowers.
- According to need and preferences, cut stems should be bunched and only flowers of the same quality should be grouped.
- Gradation of quality flowers is done the on basis of bud stage and full bloom quality, stem length, and erectness.
- Gypsophila cut stems are graded up to 10-14" long under 6-10 bunches and wrapped with rubber bands. Bunching quantity varies from 5 to 25 stems depending upon the stage of harvest and quality of stems. Transportation via truck includes 20 30 bundles in each crate of size (18×20×24 inches) and via air, 60 bunches packed in carton boxes of size (11×18×48 inches) [47].

Snapdragon

GRADE	Label colour	Minimum number of open flowers per stem	Minimum stem length (inches)	Stems per bunch
Special	Blue	15	36	12
Fancy	Red	12	30	12
Extra	Green	9	24	12
First	Yellow	6	18	12

7. WRAPPING: This step includes sleeving of a flower or bunch to prevent flower heads from any harm or damage. The use of rubber bands, strings, etc. helps in binding bunches. Corrugated card (smooth side facing the flowers), paper (waxed or unwaxed), or polyethylene (perforated, unperforated, or blister) can all be used for sleeving. The ready-made formed sleeves or prepared on the spot around each bunch via staples, tape, or polyethylene heat sealing can also be utilized [2].

8. PACKAGING: Flowers should be packaged to protect them from physical harm, water loss, and other influences while being transported. Depending on the flower, market's nature, and packaging capability, there are differences in type, size, and capacity. Rubber bands are typically used to loosely bind together groups of five, ten, twelve, or twenty stems of flowers. Individual flower bunches are wrapped with the proper packing materials, such as cellophane, Kraft paper, newspaper, tissue paper, or corrugated card stock sheet, before being placed in the container. Among typical packing materials, polypropylene film had the longest storage life (18 days), whereas regular conventional packaging had the least (9 days) [65]. The modified atmosphere packaging of carnation stored for 7 days at 5°C temperature led to reduced weight loss and presentability decay. While, snapdragons exhibited opposite effects with improved quality and increased loss in weight [37].

9. STORAGE: Low tissue metabolism during storage slows down the rate of respiration and transpiration and results in less ethylene production, further preventing the growth of bacteria and fungi [41].

Ideal storage temperature for new potential cut flowers:

Wet storage: These are kept during storage with their bases in water for a short period. During the wet storage period, more rapid nutrient breakdown takes place than flowers stored under dry conditions. Cut Delphinium stems could be stored at 4-5(°C) for 1-2 days [46]; Godetia storage at 7-8(°C) for 2-3 days; Gypsophilla were stored at 2-4 (°C) for 4-5 days and Snapdragon at 1°C for 8 weeks [33].

Dry storage: Fresh are harvested in the morning, graded, and sealed in plastic or boxes for longer periods. [30] suggested Kangaroo paw dry storage at 0-1(°C) for 14 days. Peony storage at 0°C for 4 weeks was revealed by [27] and a Stock storage period at 2°C for 4-7 days was given by [19; 20].

10. TRANSPORTATION: Due to their short-lived and highly perishable nature, flowers must be delivered quickly [62].

- Before shipping, it is important to select whether cut flowers should be packed dry or in water.
- The majority of cut flowers are now sent dry in floral boxes to far-off marketplaces by air or through huge trucks.
- Avoid transportation of flowers with fruits and vegetables.
- To induce low respiration and transpiration, always prefer cool environmental conditions or refrigerated transportation units.
- Utilization of ice or any cryogenic compounds including dry ice may be in packaging materials to remove excess flower radiation or heat through respiration [64].

11. MARKETING: Flowers marketing might occur at the local level, regional farmer level, central market, and international market (export/import). Being the commercial sector, a grower always expects high returns with maximum profit. Since the scope of the Indian market is not limited to a single country. Harvesting at a proper stage, novelty color, disease-free good volume, and long-lasting presentability, brought customer attention. Hence, meeting quality parameter standards by trusted dealers creates a convincing reputation. This will help in fetching good prices and gaining market advantage.

Surprisingly, companies and government agencies are spending more on flowers and plants to enhance the standard of living and working environments [25]. Thus, marketing plays a crucial role in ensuring satisfactory output. Government schemes, APEDA, NABARD, NHB, and Six Agri-export zones have provided ample opportunities to promote the floriculture industry in an organized manner.

CONCLUSION

Based on the scientific study proposed by different authors, it can be concluded that new potential cut flowers with various morphological and physiological factors may provide a considerable approach toward emerging market trends. The new potential flowers are filled with naturally existing enhanced presentability and bright colorful petals making them quite reliable alternatives against traditional cut flowers. Hence, new potential cut flowers can be an environmentally friendly choice that offers growers and consumers long-term beauty along with highly profitable businesses.

AUTHOR CONTRIBUTION

VB, SB, PS, ST: idea creation, data collection and analysis, manuscript preparation, edition of the manuscript.

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CONFLICT OF INTEREST
The authors declare that none of the work reported in this study could have been influenced by any known competing financial interests or personal relationship

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