Research Article

Optimal Postharvest Handling Protocols for *Consolida ambigua* - A Novel Specialty Cut Flower

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Abstract | *Consolida ambigua*, commonly known as larkspur, is a herbaceous flowering species which belongs to family Ranunculaceae. Due to its attractive, vibrant colors and plant hardiness, it is becoming increasingly prevalent in Pakistani markets as a specialty cut flower. However, limited recommendations are available for its optimal postharvest handling procedures. Therefore, a study was carried out to optimize postharvest management procedures for cut larkspurs. There were 5 experiments, viz., harvest stage, handling procedures, vase water quality, 1-MCP cards evaluation and vase preservatives. Results depicted, that larkspur stems when harvested at 25% open florets stage exhibited longest vase life (5.3 d) with greatest water uptake (127 mL). Wet handling of larkspurs, maintained, postharvest longevity when handled in (wet-dry) conditions (5.4 d) followed by (wet-wet) (5.2 d). Stems kept in distilled water were recorded greatest water uptake (99 mL) and longest vase life (5.7 d) followed by tap water (4.8 d). (1-MCP card-1) treated stems, exhibited longest vase life (4.6 d) when stored for 24 h. Lemon/lime soda (7up): distilled water (33:66) performed best with longest vase life (5.7 d), followed by Chrysal Clear Universal flower food (5.2 d). It was concluded that larkspur stems should be harvested at 25% opened floret stage, handled with wet-dry handling method, placed in distilled water containing lemon/lime soda and stored with 1-MCP card (1) for 24 h proved best for most of the tested attributes and longest postharvest life of cut stems and may be used by the stakeholders.

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Introduction

Floriculture industry is continuously looking for novel specialty cut blooms to attract more consumers. However, growers' community is reluctant to grow and market new species without awareness regarding, postharvest management (Regan and Dole, 2010). Demand for floricultural crops is quite high internationally, allowing the floral industry to flourish worldwide. Around the world, the flower industry occupies about 1.3 million hectares and makes a great contribution to national and local economies (Alarcon *et al.*, 2024). Pakistan's annual cut flower production amounts to approximately 10-12 thousand tons (Khan, 2011).

Cut flowers account for over 45% of floral commodities marketed worldwide. Pakistani farmers need sufficient guidance to meet the demands of both local consumption and exports (Ahmad *et al*., 2012a). Effective postharvest management of cut flowers is crucial for maintaining their quality and extending their life span in the vase (Darras, 2021; Usman *et al*., 2016). The majority of growers are unaware enough about the best ways to handle flowers after harvest in order to prolong their vase life and minimize postharvest losses (Macnish *et al*., 2009; Sun *et al*., 2022).

Harvesting cut flowers at the optimal growth stage helps guarantee their peak freshness, beauty, and vase life (Ahmad *et al*., 2014a). Harvesting too early or too late can significantly reduce vase life. After harvest cut flowers can be maintained wet in floral solutions or dry in boxes. It's crucial to use proper handling techniques to extend the vase life to avoid bacterial contamination (Ahmad *et al*., 2012b). Water serves a crucial role in determining the overall quality and durability of the flowers. Four primary components determine the quality of water: total dissolved solids, pH level, alkalinity and hardness (Neumaier *et al*., 2008). The quality and postharvest longevity of flowers could be significantly compromised; by high salinity water (Jezdinsky *et al*., 2024). Salt sensitivity of cut flowers depends upon the cut species (Ahmad *et al*., 2013c).

Floral preservatives are mixture of ingredients, including sugars, acidifiers, biocides and other chemicals. Carbohydrates, such as sugars, provide energy source and acidifiers, such as acetic or citric acids, assist in lowering solution pH and minimizing microbial populations (Ahmad *et al*., 2013a; Fatima *et al*., 2022). Water clogging is the prime factor of the imbalance at the stem ends of cut flowers. Preservatives with low microbial growth assist in keeping flowers turgid and fresh by maintaining optimal water balance (Budiarto *et al*., 2022).

Ethylene stress during postharvest management of cut blooms is a prime concern, resulting in early senescence and deterioration (Naing *et al*., 2021). The ethylene inhibitors, as, silver thiosulphate or 1-methylcyclopropane, are commonly used to minimize detrimental results of ethylene and also prevent stem bending caused by negative gravitropism (Ahmad and Dole, 2014b).

Limited literature is available for larkspur stems regarding stage of harvest, handling procedures, quality of water, ethylene sensitivity, and use of preservative solutions for the longest vase life. A study was conducted to scrutinize postharvest management procedures, including harvest stages, harvest procedures, vase water quality, ethylene stress sensitivity, and vase preservatives for cut larkspur stems to ensure their longest possible postharvest longevity.

Materials and Methods

Experimental site description

A study was planned at Commercial Floriculture Laboratory, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, during 2023, on cut *Consolida ambigua* (Larkspur) stems to determine, postharvest handling techniques. Cut larkspur stems were harvested, before 9:00 A.M, placed in wet buckets, after harvest and transferred to, the Commercial Floriculture Laboratory, during 1 h after harvesting. Stems, on arriving, were recut removing the lower 2-3 cm, kept in buckets having water for gaining turgor for 2 h. Afterwards, stems grading were done based on stem diameter, number of open florets and developmental stage; tagged, recut to uniform length of 60 cm, kept in vase water. Processed stems were kept, in a postharvest, evaluation room, with setup, temperature, at 22 ± 2°C along with 50% ±10% relative humidity, 12 h of light provided with, white, fluorescent lamps. Data were recorded daily till the end of postharvest longevity.

Expt. 1. Harvest stage

Stems were harvested and processed as described earlier. There were three treatments each with five replications having two stems in each replication. Stems were kept in glass jars with 300 mL of distilled water till end of experiment. Treatments included bud stage (closed florets stage), partially opened stage (25% florets open) and fully (50% florets opened stage).

Expt. 2. Handling procedures

In 2nd experiment regarding handling procedures, stems were divided into two groups after harvest; half were kept in buckets containing water, while other half group was kept in cardboard boxes. After one hour, half stems from the floral box were transferred to the wet bucket, while the other half group was retained in box. Similarly, half stems from wet conditions were shifted to box leaving the other half group in the bucket for another one hour. Afterwards, stems were processed and placed in glass jars with two stems in each jar for evaluation until termination.

Expt. 3. Vase water quality

After processing, stems were kept in various types of vase water, viz., distilled, tap and canal water until termination. Stems were placed in respective treatments having five replicates of two stems each.

Expt. 4. Storage with or without 1-MCP cards

Stem were processed and kept in floral cardboard boxes containing control (no card), 1-MCP (card -I) and 1-MCP (card -II) at 25 ± 2°C temperature, for various storage durations i.e. (24, 48 and 72 h), respectively. Respiration rate of stems was recorded before opening the box. Stems were recut, weighed and shifted to jars for determination of vase life.

Expt. 5. Vase preservatives

Stems were processed as described earlier. Treatments included control (distilled water), 1% sucrose (S) + 150 mg L^{-1} citric acid (CA), 1% sucrose (S) + 100 mg L^{-1} salicylic acid (SA), 1% sucrose (S) + 100 mg L^{-1} aluminum sulphate (AS), lemon/lime soda (7up): distilled water (33:66), 1% sucrose (S) + 4 mL L^{-1} lemon juice, 1% sucrose + 4mL L^{-1} vinegar, 1% sucrose + 15 mL L^{-1} bleach and Chrysal.

Data collection

Data were collected on following parameters using standard procedures in each experiment: Change in fresh weight (g): Weight was measured with electric weighing machine (A & D Gulf, Model DM-305F) using formula, FW (g) = (W1- W2) Flower quality: Flower quality of stems was rated on a scale of 0-9 as 0 = bad quality, 6 = medium quality and 9 = best quality (Cooper and Spokas, 1991). Dry weight (g): at the end of trial, shade dried stems were packed in brown paper bags and dried in oven at 70°C for 72 hours. Weigt of two stems per replicate was recorded. Water uptake (mL): Volume of absorbed water during first seven days of vase life was determined by measuring the volume of vase water remaining on day 7 using following formula: Water uptake (mL) = (S0-S7). Ion leakage (%): Petals were rubbed with sand for 4-5 min., then placed in test tubes after rinsing with distilled water. Test tube was also filled with 15 mL distilled water, tied with thin polythene film, kept on orbital shaker for 10 min. and EC_1 was recorded. EC_2 was recorded after again keeping on orbital shaker for further 100 min. Ion leakage (%) = $EC_2/EC_1 \times 100$ (for harvest stage, handling procedures, water quality, pulsing and vase preservative experiments only). Electrical conductivity EC (µS.cm^{-1}) and pH change: Solution EC and pH was recorded on day 0 of the experiments and when 50% of stems were terminated using electrical conductivity meter (Hanna, HI9811-5). Their differences were recorded, and means were worked out. Vase life (days): Vase life was recorded till each stem exhibited >50% termination symptoms (Ahmad *et al*., 2013c). Termination symptoms: Termination symptoms (%) viz. petal necrosis (PN), bent neck (BN), and stem end decay (SED), were recorded on stems showing ≥50% of symptoms affected stems. Stems with indication of symptoms were labeled as (1-0) as 1= Yes and 0 = No and percentage data was recorded.

Statistical analysis

Data were worked out using Fisher's least significant difference (LSD), test at P≤0.05, to calculate means and conduct analysis of variance (ANOVA) procedures using General Linear Models (Steel *et al*., 1997).

Results and Discussion

Harvest stage

Larkspur stems were harvested, at the half-bloomed stage, extended postharvest life (5.3 d) followed, by bud stage (5.1 d) (Figure 1).

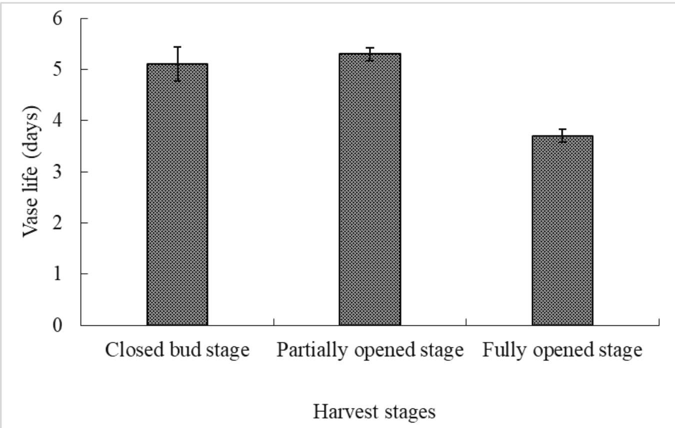

Figure 1: *Effect of harvest stages on vase life of larkspur stems. Bars denote mean values of 10 stems ± Standard Error.*

Highest change in fresh weight (0.8 g) was recorded in fully opened (50-60% open florets) stage stems. Highest change in EC (74 µS cm^{-1}), pH (2.4) and

Table 1: *Effect of different harvest stages on fresh weight change, solution EC change, water uptake, pH change, flower quality change, ion leakage and petal necrosis of cut larkspur stems. n=10.*

Treatments (Harvest stages)	Fresh weight change (g)	Solution EC change (µS cm^{-1})	Water uptake (mL)	Solution pH change	Flower quality change	Ion leakage (%)	Petal necrosis (%)
Closed bud stage	0.7 ab[z]	56 b	78 b	0.9 b	3.2 b	117.5 ab	50 a
Partially (25%) opened stage	0.5 b	40 c	127 a	1.0 b	0.6 c	127.6 a	0 b
Fully opened stage	0.8 a	74 a	149 a	2.4 a	5.8 a	109.1 b	0 b
Significance[y]	0.050	0.0003	0.0007	0.0011	≤0.0001	0.0067	0.0028

[z]*Means separation within columns by Fisher's LSD at P≤0.05.*
[y]*P values were obtained using general linear models (GLM) procedures of statistix (version 8.1, analytical software) for significant effects of different harvest stages on cut larkspur stems.*

Table 2: *Effect of various handling procedures on fresh weight change, solution EC change, water uptake, pH change and dry weight of cut larkspur stems. n=10.*

Treatments (Handling procedures)	Fresh weight change (g)	Solution EC change (µS cm^{-1})	Water uptake (mL)	pH change	Dry weight (g)
Wet-Wet	0.5	36 a[z]	112 a	0.1 a	3.3
Wet-Dry	0.7	8 b	72 b	0.8 ab	3.2
Dry-Wet	0.7	14 b	66 b	0.6 bc	3.2
Dry-Dry	1.1	30 a	73 b	0.5 c	3.1
Significance[y]	NS	0.0028	0.0011	0.0029	NS

[z]*Means separation within columns by Fisher's LSD at P≤0.05.*
[y]*P values were obtained using general linear models (GLM) procedures of statistix (version 8.1, analytical software) for significant effects of different handling procedures on cut larkspur stems.*
[NS]Non-significant at P>0.05.

flower quality (5.8) was exhibited in stem harvested at fully opened stage (Table 1). These findings are similar with a study on harvest stage of chrysanthemums found out that stems harvesting at standard stage extended vase life compared to stems picked later (Yoo and Roh, 2015). Larkspur stems harvested at closed bud stage exhibited least water uptake (78 mL) followed by partially opened stage (127 mL) and fully opened stage (149 mL). Petal necrosis (PN) was only observed in bud stage (50%). Highest ion leakage (127.6%) was recorded in partially opened stage followed by closed bud stage (117.5%). Data regarding stem end rotting (SER) had no significant differences and averaged (43%) in all tested treatments. These results are in accordance with the findings on *Paeonia lactiflora* harvested at tight bud stage, which exhibited longest vase life (7.6 d) (Sun *et al*., 2022). Tuberose stems when harvested at two florets opened stage had the greater vase life and minimal abscised florets (Asif *et al*., 2016). Moreover, cut blooms, harvested early at bud stage, had longer vase life compared to those harvested at fully bloomed flower stage (Ahmad *et al*., 2014b).

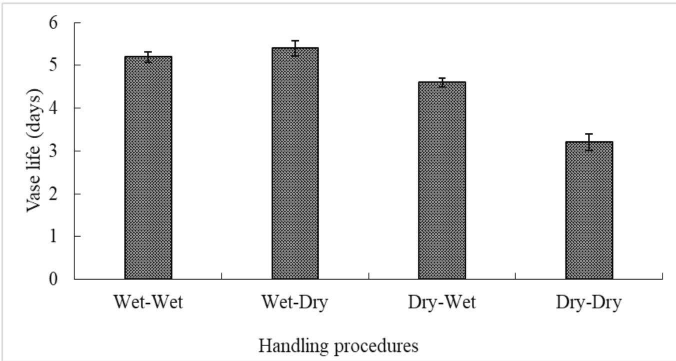

Figure 2: *Effect of handling procedures on vase life of cut larkspur stems. Bars denote mean values of 10 stems ± standard error.*

Handling procedures

Larkspur stems handled in wet-dry method remained fresh for 5.4 days followed by wet-wet handling with 5.2 days vase life (Figure 2).

Wet storage maintained good stem turgor to allow closed florets to open more quickly and kept stems fresh for longer periods. There were no significant differences for change in fresh weight or dry weight, which averaged 0.81 g and 3.2 g, respectively (Table 2). Wet stored stems absorbed more water (112 mL)

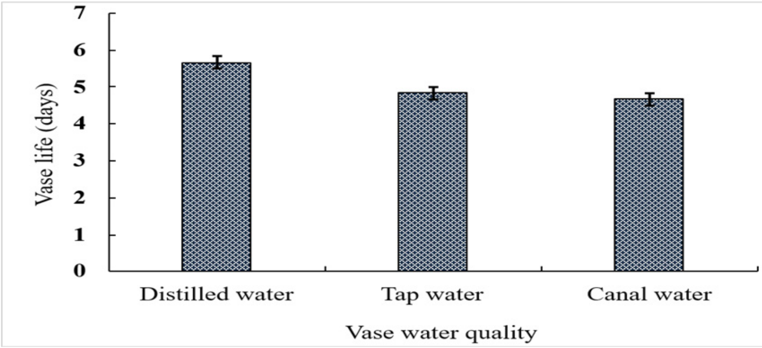

Figure 3: *Effect of vase water quality on vase life of cut larkspur stems. Bars denote mean values of 10 stems ± Standard Error.*

Table 3: *Effect of vase water quality on solution EC change, water uptake, solution pH change, flower quality change, ion leakage and bacterial count of cut larkspur stems. n=10.*

Treatments (Vase water quality)	Solution EC change (µS cm^{-1})	Water uptake (mL)	Solution pH change	Flower quality change	Ion leakage (%)	Bacterial count (cfu/mL)
Distilled water	28.3 b[z]	99.2 a	-0.65	3.5 b	110.9 a	40 c
Tap water	101.6 a	65.0 ab	0.73 a	3.8 b	100.6 ab	164 a
Canal water	103.3 a	46.6 b	-0.03 b	6.0 a	92.9 b	139 b
Significance[y]	0.050	0.050	0.0077	0.011	0.0067	<0.0001

[z]*Means separation within columns by Fisher's LSD at P≤0.05.*
[y]*P values were obtained using general linear models (GLM) procedures of statistix (version 8.1, analytical software) for significant effects of vase water quality on cut larkspur stems.*

and maintain turgor for more days compared to dry storage (73 mL). These findings are similar to the results with gerbera stems stored in wet paper towel or in water for 1-2 hours improved vase life and overall flower quality compared to dry storage. Dry stored larkspur stems had shorter vase life (3.2 days) when stored for longer durations. Longer dry storage durations resulted in reduction of vase life and quality for most flowers (Zhao *et al*., 2018). Highest change in EC (36 µS cm^{-1}) was recorded in wet (from field to jars) treatment. Meanwhile, greatest change in pH (0.8) was recorded in stems handled wet-dry (wet from field to lab but dry from lab to jars) treatment.

Vase water quality

Larkspur stems held in distilled water had greatest water intake (99 mL) and longer vase life (5.7 d) followed by tap water (4.8 d) (Figure 3).

Highest change in EC was recorded for stems kept in canal water (103.3 µS cm^{-1}) followed by tap water (101.6 µS cm^{-1}). Meanwhile, change in EC was lowest (28.3 µS cm^{-1}) for stems placed in distilled water (Table 3). Water with low pH is more easily absorbed by the cut stems. Lower pH slows down the growth of microbes and assists in proper hydration of stems to maintain turgor. Least flower quality change (3.5) was noted, in stems held in distilled water followed by tap water (3.8) and highest change (6.0) in canal water. Stems kept in tap water exhibited highest microbial colonies (164 cfu mL^{-1}) followed by canal water (139 cfu mL^{-1}). Least number of microbial colonies (40 cfu mL^{-1}) was recorded in distilled water. Change in fresh weight, stem end rottening (SER), bent neck (BN) and petal necrosis (PN) were not significantly different and averaged 1.02 g, 88.3%, 38.6% and 53.3%, respectively (data not presented). Various sources of water can have a wide range of quality, including high salinity, varying pH levels, and microbial contamination (van Doorn and van Meeteren, 2023).

Storage with or without 1-MCP cards

Larkspur cut stems stored along with, 1-MCP cards had better flower quality and vase life. Longest postharvest life was noted in stems stored with 1-MCP (card-I) (4.6 days) followed by 1-MCP (card-II) (3.6 days) for 24 h, 25±2°C (Figure 4). Stems stored without 1-MCP card (control) exhibited shortest vase life 2.6 days after 24 h, 2.0 days after 48 h and 1.6 days after 72 h, with more petal shattering compared to stems treated with 1-MCP cards. Larkspur cut stems are highly sensitive to ethylene causing petal shattering abscission if exposed to ethylene during storage or

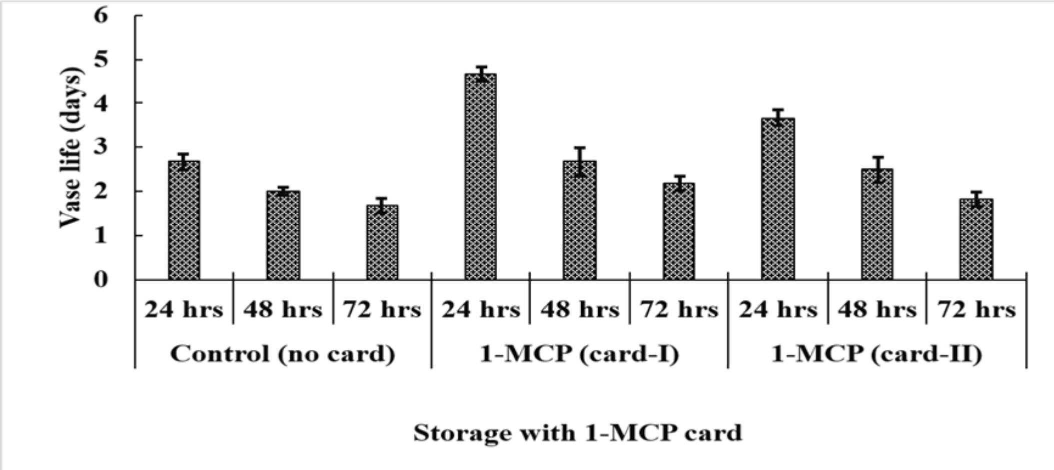

Figure 4: *Effect of storage with or without 1-MCP cards on vase life of cut larkspur stems. Bars denote mean values of 10 stems ± Standard Error.*

Table 4: *Effect of various storage methods (with or without 1-MCP cards) along with different storage durations on solution EC change, solution pH change, fresh weight change, flower quality change, water uptake, dry weight and respiration rate of cut larkspur stems. n=10.*

Treatments 1-MCP-card	Storage durations (h)	Solution EC change (μS cm^{-1})	Solution pH change	Fresh weight change (g)	Flower quality change (1-9)	Water uptake (mL)	Dry weight (g)	Respiration rate (%)
Control (No 1-MCP card)	24	8.3 d[z]	0.5 c	1.7 bc	5.5 a	30 bc	3.3 c	0.02 cd
	48	43.3 bc	1.0 b	3.0 a	5.1 a	20 bc	4.5 ab	0.02 cd
	72	13.3 cd	-0.1 e	1.5 c	5.1 a	16 c	4.9 a	0.04 a
1-MCP (card-I)	24	1.6 d	0.4 cd	2.5 ab	2.1 b	36 b	3.5 c	0.01 bcd
	48	66.6 ab	1.5 a	1.7 bc	5.2 a	56 a	4.5 ab	0.03 abc
	72	10.0 cd	-0.1 e	1.6 bc	4.6 a	26 bc	3.9 bc	0.03 abcd
1-MCP (card-II)	24	5.0 d	0.6 bc	2.3 abc	3.0 b	63 a	3.4 c	0.01 d
	48	80.0 a	0.5 cd	2.3 abc	5.3 a	16 c	3.7 c	0.02 abcd
	72	16.6 cd	0.1 de	1.56 c	4.5 a	16 c	5.1 a	0.03 ab
Significance[y]								
Storage method (SM)		NS	NS	NS	0.0041	0.0113	NS	NS
Storage duration (SD)		<0.0001	<0.0001	0.0146	0.0004	0.0013	0.0002	0.028
SM × SD		NS	0.0028	0.0464	0.0069	0.0013	0.0309	NS

[z]*Means separation within columns by Fisher's LSD at P≤0.05.*
[y]*P values were obtained using general linear models (GLM) procedures of statistix (version 8.1, analytical software) for significant effects of 1-MCP cards and storage durations on cut larkspur stems.*
[NS]*Non-significant at P>0.05.*

transportation. Cut flowers are highly perishable commodities and are highly sensitive to ethylene (Naing *et al*., 2021). Anti-ethylene compound like 1-methylcyclopropene (1-MCP) is being primarily used to prevent the deleterious impacts of ethylene (Ahmad and Dole, 2014b).

Cut carnations and delphinium stems treated with 1-MCP cards doubled vase life of carnations and significantly improved vase life of delphinium as compared to untreated control flowers (Ichimura *et al*., 2002). Flower quality change (2.1) was noted, with 1-MCP cards when stored for 24 h compared to control (5.5). Greatest water uptake (63 mL) was recorded in stems treated with 1-MCP card (II) for 24 h, followed by 1-MCP card (I) (57 mL) for 48 h. (Table 4). The production of ethylene closely correlates with the state of freshness or senescence. Cut stems when treated with anti-ethylene agents resulted in suppressing ethylene production by lowering respiration rate (Wang *et al*., 2020). Storage method has no effect (P>0.05) on change in EC, pH and fresh or dry weights. Moreover, storage duration had a significant effect on all tested parameters. Ethylene induction causes early petal senescence and petal bleaching in cut blooms.

Use of MCP cards had no significant effect (P>0.05) on change in EC, change in pH and change in fresh or dry weights. Moreover, storage duration had a significant effect on all tested parameters. 1-MCP cards significantly prolonged the vase life of gladioli by minimizing, ethylene production (Darras and Kargakou, 2019; Wongjunta *et al*., 2021). Respiration rate was highest with no 1-MCP cards (control) 0.02% for 24 and 72 h and lowest with 1-MCP cards 0.01, 0.02 and 0.03% for 24, 48 and 72 h, respectively. 1-Methylcyclopropane, a gaseous inhibitor, of ethylene action, assists in preventing the deleterious effects of ethylene by reducing respiration rate (Thakur, 2020).

Vase solutions

Cut larkspur stems when placed in lemon/lime soda (7up): distilled water (33:66) exhibited longest vase life (5.7 d) followed by Chrysal Clear Universal Flower Food (4.9 d). Use of 1% S along with 150 mg L^{-1} CA or 100 mg L^{-1} AS, were statistically similar with 4.4 and 4 d vase life, respectively. Stem treated with distilled water only (control) had shortest vase life (3.2 d) with highest leaf wilt (LW) (60%) and petal necrosis (PN) (20%) (Figure 5).

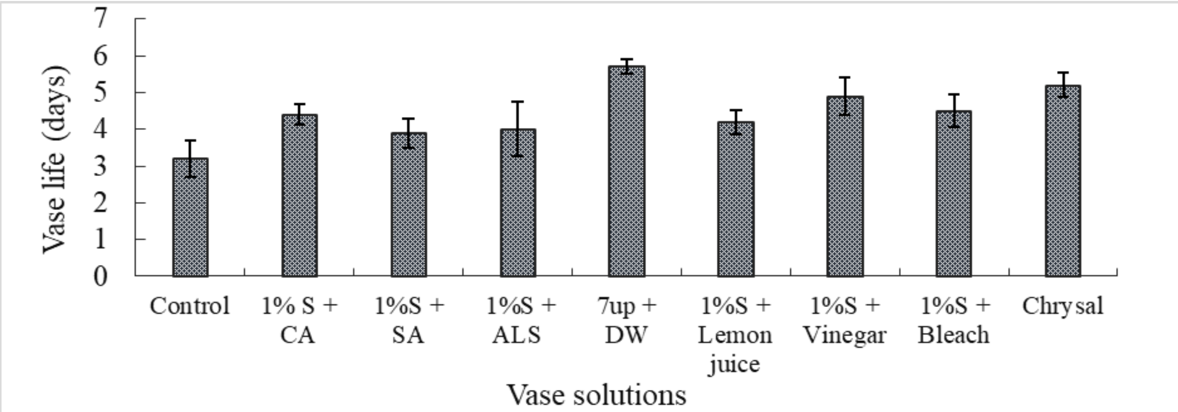

Figure 5: *Effect of various vase preservatives on vase life of cut larkspur stems. Bars denote mean values of 10 stems ± Standard Error. (S = Sucrose, CA = 150 mg L^{-1} Citric acid, DW = Distilled water, SA = 100 mg L^{-1} Salicylic acid, AS =100 mg L^{-1} Aluminum sulphate, Lj = 4 mL L^{-1} Lemon juice, Vin = 4 mL L^{-1} vinegar, BL = 15 mL L^{-1} bleach, Chrysal = Chrysal Clear Professional flower food).*

Table 5: *Effect of different vase preservatives on water uptake, solution pH change, solution EC change, leaf wilt and petal necrosis of cut larkspur stems. n=10.*

Treatments (Vase solutions)	Water uptake (mL)	Solution pH change	Solution EC change (µS cm^{-1})	Leaf wilt (%)	Petal necrosis (%)
Distilled water (Control)	184 a[z]	-2.7 e	24 e	60 b	20 ab
1% S + 150 mg L^{-1} CA	100 ef	-0.8 bcd	70 d	0 c	0 b
1% S + 100 mg L^{-1} SA	114 de	-0.12 ab	126 c	0 c	0 b
1% sucrose+ 100 mg L^{-1} AS	166 b	-0.56 bc	448 a	0 c	40 ab
Lemon/lime soda: distilled water (33:66)	142 c	-0.82 cd	384 b	0 c	0 b
1% sucrose+ 4 mL L^{-1} lemon juice	176 ab	-1.42 d	16 e	0 c	60 a
1% sucrose + 4mL L^{-1} vinegar	128 cd	0.47 a	-28 f	100 a	20 ab
1% sucrose + 15 mL L^{-1} bleach	90 f	-2.88 e	-174 g	100 a	0 b
Chrysal Clear Professional flower food	60 g	-6.36 b	122 c	100 a	0 b
Significance[y]	<0.0001	<0.0001	<0.0001	<0.0001	0.05

[z]*Means separation within columns by Fisher's LSD at P≤0.05.*
[y]*P values were obtained using general linear models (GLM) procedures of statistix (version 8.1, analytical software) for significant effects of vase solutions on cut larkspur stems.*

Highest change in EC (448 µS cm^{-1}) was recorded in stems kept in 1% S + 100 mg L^{-1} AS followed by lemon/lime soda (7 up): distilled water (33:66) (384 µS cm^{-1}). Highest leaf wilting was recorded in stems kept in 1% S along with 4 mL L^{-1} vinegar or 15 mL L^{-1} bleach (Table 5). Treating stems with carbohydrates is required to assist in bud opening and improving flower quality (Ahmad *et al*., 2014b). The longevity of cut roses can be extended using different preservatives. Cut spikes of tuberose with 50 mg L^{-1} SA with or without 10% sucrose (S) proved effective for extending vase life (Asif *et al*., 2016). Deionized water or 4% sucrose had larger petal area and flower diameters compared to all other preservatives (Ahmad *et al*., 2013b). Commercial floral preservative Chrysal Clear Professional flower food has beneficial effect on the vase life of cut flower species, but these preservatives are not available in developing countries like Pakistan. (Fatima *et al*., 2022). Various homemade folk preservatives can be used including lemon/lime soda, lemon juice, vinegar bleach and aspirin tablets as folk preservative solutions for extending longevity of cut stems (Ahmad and Dole, 2014a).

Conclusions and Recommendations

Larkspur stems must be harvested. at 25% florets opened, handled in wet baskets, from harvest to packing, kept in distilled or at least tap water, during processing and may be stored for 24-48 h with 1-MCP (card-1). Moreover, lemon/lime soda: distilled water (33:66) may be used to extend postharvest longevity and quality of cut stems and may be used by florists, and other marketing stakeholders for handling.

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Novelty Statement

Larkspur is relatively new cut flower crop and its demand is increasing day by day in the region. Optimal postharvest handling protocols of cut flowers are yet not available to growers and stakeholders and these findings will minimize postharvest losses by minimal change in visual quality of cut larkspur stems.

Author's Contribution

Tazkia Hussain: Conducted experiments, data collection, data analysis and manuscript writing.
Iftikhar Ahmad: Conceived idea, provided resources along with technical guidance and supervised the experiment, as well as reviewed manuscript technically.
Huda Hameed: Assisted in data collection and data analysis
Muhammad Asif: Supervised the experiment and manuscript review.

Generative AI and AI-assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

References

Ahmad, I. and J.M. Dole. 2014a. Postharvest performance of cut marigold, rose, and sunflower stems as influenced by homemade and commercial floral preservatives. *Turk. J. Agric.*, 38(6): 916-925. https://doi.org/10.3906/tar-1402-31

Ahmad, I. and J.M. Dole. 2014b. Optimal postharvest handling protocols for *Celosia argentea* var. cristata L. 'Fire Chief' and *Antirrhinum majus* L. 'Chantilly Yellow'. Sci. Hortic., 172: 308-316. https://doi.org/10.1016/j.scienta.2014.04.026

Ahmad, I., J.M. Dole and P. Nelson. 2012a. Nitrogen application rate, leaf position and age affect leaf nutrient status of five specialty cut flowers. Sci. Hortic., 142: 14-22. https://doi.org/10.1016/j.scienta.2012.04.009

Ahmad, I., J.M Dole, A. Amjad and S. Ahmad. 2012b. Dry storage effects on postharvest performance of selected cut flowers. Horttechnol., 22:463-469. Doi: https://doi.org/10.21273/HORTTECH.22.4.463

Ahmad, I., J.M. Dole, A.S. Carlson and F.A. Blazich. 2013a. Water quality effects on postharvest performance of cut calla, hydrangea, and snapdragon. Sci. Hort. 153:26-33. Doi: https://doi.org/10.1016/j.scienta.2013.01.015

Ahmad, I., J.M. Dole, M. Saleem, M.A. Khan, A. Akram and, A.S. Khan. 2013b. Preservatives and packaging material have an impact on the post-harvest longevity of cut *Rosa hybrid* L. Kardinal flowers J. Hortic. Sci. Biotechnol., 88(3): 251-256. https://doi.org/10.1080/14620316.2013.11512963

Ahmad, I., R.U. Saquib, M. Qasim, M. Saleem, A.S. Khan and M. Yaseen. 2013c. Humic acid and cultivar effects on growth, yield, vase life, and corm characteristics of gladiolus. Chil. J. Agric., Res.73: 339 344. Doi: http://dx.doi.org/10.4067/S0718 58392013000400002

Ahmad, I., J.M. Dole and F.A. Blazich. 2014a. Effects of daily harvest time on postharvest longevity, water relations, and carbohydrate status of selected specialty cut flowers. Hort. Science., 49(3): 297-305. http://dx.doi.org/10.21273/hortsci.49.3.297

Ahmad, I., J.M. Dole, F. Schiappacasse, M. Saleem and E. Manzano. 2014b. Optimal postharvest handling protocols for cut 'Line Dance' and 'Tap Dance' Eremurus inflorescences. Sci. Hortic., 179: 212-220. https://doi.org/10.1016/j.scienta.2014.09.031

Alarcón, A.G.M., G.A. Lorenzo and L. Mascarini. 2024. Effects of water stress on the post-harvest quality of cut Lilium flowers. Ornam Hortic., 30242-647. doi: http://dx.doi.org/10.1590/2447-536x.v30.e242647

Asif, M., I. Ahmad, M. Qasim and R. Ahmad. 2016. Effect of pulsing with various preservatives on postharvest performance of cut *Polianthes tuberosa* L. 'Single' spikes. Pak. J. Agric. Sci., 53(3): 331-338. http://doi.org/10.21162/PAKJAS/16.5436

Budiarto, K., L. Zamzami and O. Endarto. 2022. Effect of salicylic and ascorbic acids on post-harvest vase life of chrysanthemum cut flowers. Sci. Hortic., 49(1): 38-47. https://doi.org/10.17221/ 151/2020-HORTSCI

Cooper, R.J. and L.A. Spokas. 1991. Growth, quality and foliar iron concentration of Kentucky blue grass treated with chelated iron sources. J. Am. Soc. Hortic. Sci. 11:798-801. https://doi.org/10.21273/JASHS.116.5.798

Darras, A. 2021. Overview of the dynamic role of specialty cut flowers in the international cut flower market. Horttechnol., 7(3): 51-60. https://doi.org/10.3390/ horticulturae 7030051

Darras, A.I. and V. Kargakou. 2019. Postharvest physiology and handling of cut *Spartium junceum* inflorescences. Sci. Hortic., 252: 130-137. https://doi.org/10.1016/j.scienta.2019.03.048

Fatima, K., I. Ahmad, J.M. Dole, N. Ahmad, M. Asif, K. Ziaf and K. Fatima. 2022. Folk floral preservatives extend postharvest longevity of *Eustoma grandiflorum* L. Sci. Hortic., 301: 111-132. https://doi.org/10.1080/14620316.2013.11512963

Ichimura, K., H. Shimizu, T. Hiraya and T. Hisamatsu. 2002. Effect of 1-methylcyclopropene (1-MCP) on the vase life of cut carnation, delphinium and sweet pea flowers. Bull. Natl. Inst. Flor. Sci., 2(1): 8.

Jezdinsky, A., J.K. Slezak, M. Vachun, R. Pokluda, J. Uher. 2024. Effect of saline water on the vase life of *Narcissus poeticus* L. flowers. Folia Hortic., 36(1): 95-117. https://doi.org/10.2478/fhort-2024

Khan, M.J. 2011. Horticulture in Pakistan: planning perspective. In Presentation at International Seminar on Horticulture and Agribusiness in Developing Countries at UAF. pp. 1-17.

Macnish, A.J., A. de Theije, M.S. Reid and C.Z. Jiang. 2009. An alternative postharvest handling strategy for cut flowers dry handling after harvest. Acta Hort., 847: 215-221. http://dx.doi.org/10.17660/ActaHortic.2009.847.27

Naing, A.H., M.T. Soe, J.H. Yeum and C.K. Kim. 2021. Ethylene acts as a negative regulator of the stem bending mechanism of different cut snapdragon cultivars. Front. Plant. Sci., 12: 74-538. https://doi.org/10.3389%2Ffpls.2021.745038

Neumaier, D., E. Bausbach, M. Simon, M. Tisch, and T. Winkelmann. 2008. Effect of time of harvest, water quality and cut flower food on vase life of Cyclamen cut flowers. *IX* Int. Sympos. Postharv. Qualit. Ornament. Plant., 847: 269-274. https://doi.org/10.17660/ActaHortic.2009.847.35

Niu, G., Y. Jiang, H. Zhang and X. Wang. 2019. Harvesting, handling and storage of cut roses. In: Handbook of Postharvest Technology, Springer. Cham., pp. 355-369. http://doi.org/10. 3390/plants11202713

Regan, E.M. and J.M. Dole. 2010. Postharvest handling procedures of *Matthiola incana* 'Vivas Blue'. Postharvest Biol. Technol., 58(3): 268-273. http://doi.org/10.1016/j.postharvbio.2010.07.011

Steel, R.G. D., J.H. Torrie, D.A. Dicky. 1997.

Principles and Procedures of Statistics: A Biological Approach. 3rd ed. McGraw Hill Book Co. Inc., New York, USA. P. 328-345.

Sun, J., H. Guo and J. Tao. 2022. Effects of harvest stage, storage, and preservation technology on postharvest ornamental value of cut peony (*Paeonia lactiflora*) flowers. Agron., 12(2): 230. https://doi.org/10.3390/agronomy12020230

Thakur, N. 2020. A review on the effect of storage methods and packaging material on the post-harvest longevity of cut flowers. Int. J. Chem. Stud., 8(3): 2375-2379.doi: https://doi.org/10.22271/chemi.2020.v8.i3ah.9568

Usman, M., A. Ali, A. Ghafoor, S. Baig, M. Hashim and M. Rehman. 2016. An econometric estimation of postharvest losses of cut flowers in Punjab, Pakistan. Pak. J. Sci., 68(3): 272. http://ssrn.com/abstract=3498475

Van Doorn, W.G., and U. Van Meeteren. 2023. Flower opening and closure: a review. J. Exp. Bot., 54(389): 1801-1812. http://doi.org/10.1093/jxb/erg213

Wang, C., H. Fang, T. Gong, J. Zhang, L. Niu, D. Huang and W. Liao. 2020. Hydrogen gas alleviates postharvest senescence of cut rose 'Movie star 'by antagonizing ethylene. Plant Mol. Biol., 102 (3): 271-285. http://dx.doi.org/10.1007/s11103-019-00946-3

Wongjunta, M., C. Wongs-Aree, S. Salim, S. Meir, S. Philosoph-Hadas and M. Buanong. 2021. Involvement of ethylene in physiological processes determining the vase life of various hybrids of Mokara orchid cut flowers. Agron., 11(1): 160. https://doi.org/10.3390 / agronomy11010160

Yoo, Y.K. and Y.S. Roh. 2015. Effects of shipping temperature and harvesting stage on quality and vase life of cut flowers in *Dendranthema grandiflorum* 'Baekma' for export. Hortic. Sci. Technol., 33(1):61-69. https://doi.org/10.7235/hort.2015.14082

Zhao, H., C. Shu, X. Fan, J. Cao and W. Jiang. 2018. Near-freezing temperature storage prolongs storage period and improves quality and antioxidant capacity of nectarines Sci. Hort., 228: 196-203 https://doi.org/10.1016/j.scienta.2017.10.032