



Check for
updates



Review Article

Uncovering the Potential of Ethylene Inhibitors on Delaying Ethylene Mediated Senescence and Preserving Cut Life of Climacteric Flowers

Ayesha Manzoor¹, Tanveer Hussain², Naeem Akhtar¹, Muhammad Waqas Azam², Syed Awais Sajid³, Ahsan Hammad⁴, Tamoor Hussain¹, Muhammad Arslan¹, Muhammad Saqib Naveed¹

¹ Barani Agricultural Research Institute, Chakwal, Pakistan.

² Department of Horticulture, PMAS- Arid Agriculture University Rawalpindi, Pakistan.

³ Millets Research Station, Rawalpindi, Pakistan.

⁴ Department of Plant Breeding and Genetics, PMAS Arid Agriculture University Rawalpindi, Pakistan.

ABSTRACT

Maintaining the vase life and quality of cut flowers is one of the main obstacle in floriculture industry. Cut flowers, especially climacteric ones have very short life span attributed due to outburst of respiration and ethylene synthesis during senescence. This increase is related to autocatalytic reaction in which exogenous ethylene initiate biosynthesis of endogenous ethylene, activating enzymes and genes involved in ethylene synthesis. Ethylene causes petal wilting and abscission, leaf yellowing and abrupt or premature death of flowers. Flower senescence in ethylene synthesis flowers can't be eliminated but can be delayed using by application of ethylene inhibitors. Ethylene inhibitors (biosynthesis and action) can minimize the premature flower senescence in response to endogenous ethylene production. Application of these inhibitors as pulsing or holding solution reduced ethylene biosynthesis by inhibiting enzymes activities or used antagonistic molecules to bind with ethylene receptors thus inhibiting downstream signaling. This review sheds light on ethylene inhibitors types, mode of action, impact on vase life and quality of cut flowers and their limitations. This comprehensive write-up will not only help the florists, but it will provide combined and detailed information to researchers in designing their research studies.

Keywords: Action Inhibitor, ACC Enzyme, Ethylene Biosynthesis, Endogenous Ethylene, Receptors, Oxidative Stress.



Correspondence

Ayesha Manzoor
manzoorayesha12@yahoo.com

Article History

Received: July 13, 2025

Accepted: August 28, 2025

Published: August 30, 2025



Copyright: © 2024 by the authors.
Licensee: Roots Press,
Rawalpindi, Pakistan.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license:
<https://creativecommons.org/licenses/by/4.0>

INTRODUCTION

Flowers are an integral part of plant survival as their attractive color and captivating fragrance plays an important role in reproduction and seed production. Despite their ecological importance, they have a reduced or limited life span (Rani and Singh, 2014). Flower longtivity is considered as an important traits to evaluate cut flower quality and flowers having prolonged vase life perceived to be of higher quality (Wang et al., 2023). However, as soon as cut flower detached from mother plant, factors related to senescence activates (Gun, 2020). Cut flower senescence is a metabolic event occur due to separate or various interconnected physiological process take place in morphological organs of flower. These process includes ethylene production, respiration, degradation of carbohydrates and soluble sugar, loss of membrane permeability, transpiration, hormonal imbalance, activation of enzymes related to petal wilting and abscission, fatty acid breakdown and protein and nucleic acid degradation (Wu et al., 2017; Kumar et al., 2022).

According to research studies, flower senescence consists of controlled disassembly of corolla cells by a phenomena of apoptosis, vacuolar and necrotic PCD (Rani and Singh, 2014). As flower senescence triggered by internal and external factors. Internal factors such as ethylene synthesis is considered as an important phytohormone in regulating flower senescence (Wu et al., 2017). During aging of cut flowers, ethylene production reach or exceed to specific level, a large amount of ethylene is biosynthesized in floral organs to accelerate respiratory rate in order to release excess respiratory heat, results in quick senescence of a flower (Wang et al., 2020a). Exogenous ethylene in close spaces also affect plants/cut flower and rendered them unsaleable (Olsen et al., 2015).

Methodology

We could not find any detailed and comprehensive study on ethylene inhibitors effect on cut flower vase life. Hence a review was formulated to answer the following questions “How inhibitors reduced flower senescence?”, “Role in maintenance of vase life through morphological, physiological and biochemical approach” etc. This is the first detailed review on ethylene inhibitors types and their role in extension of cut flower life, therefore, research material was collected from different search engines (Google scholar, NCBI, ScienceDirect, Academia.edu and ResearchGate etc). Keywords used to search research studies were ethylene action inhibitor, biosynthesis, cut flowers, gene expression and flower senescence. Overall, 85-90 research publications were studied and their results were incorporated in this review.

Ethylene

Final stage of cut flower starts from petal wilting, flower withering, petal discoloration, petal desiccation and petal abscission, mainly due to ethylene involvement. Ethylene is an important hormone in regulating flower senescence and exert effects as low as $0.1 \mu\text{L L}^{-1}$ concentration in ethylene sensitive flowers. It initiate petal wilting by inhibiting cell expansion through aquaporins regulation (proteins involved in water transport), leading to negative water balance affecting vase life and increase flower abscission by initiating abscission zone formation (Costa et al., 2020). Ethylene plays as a key signal in plant cell and tissue senescence by activating gene expression and activities of cell degrading enzymes (proteinases, polygalacturonases, lipases, chlorophyllases, pectinase and lipoxygenase). Moreover, increase in respiration rate not only deplete carbohydrate reserves but also leads to oxidative burst (Figure 1) (Darvish et al., 2021).

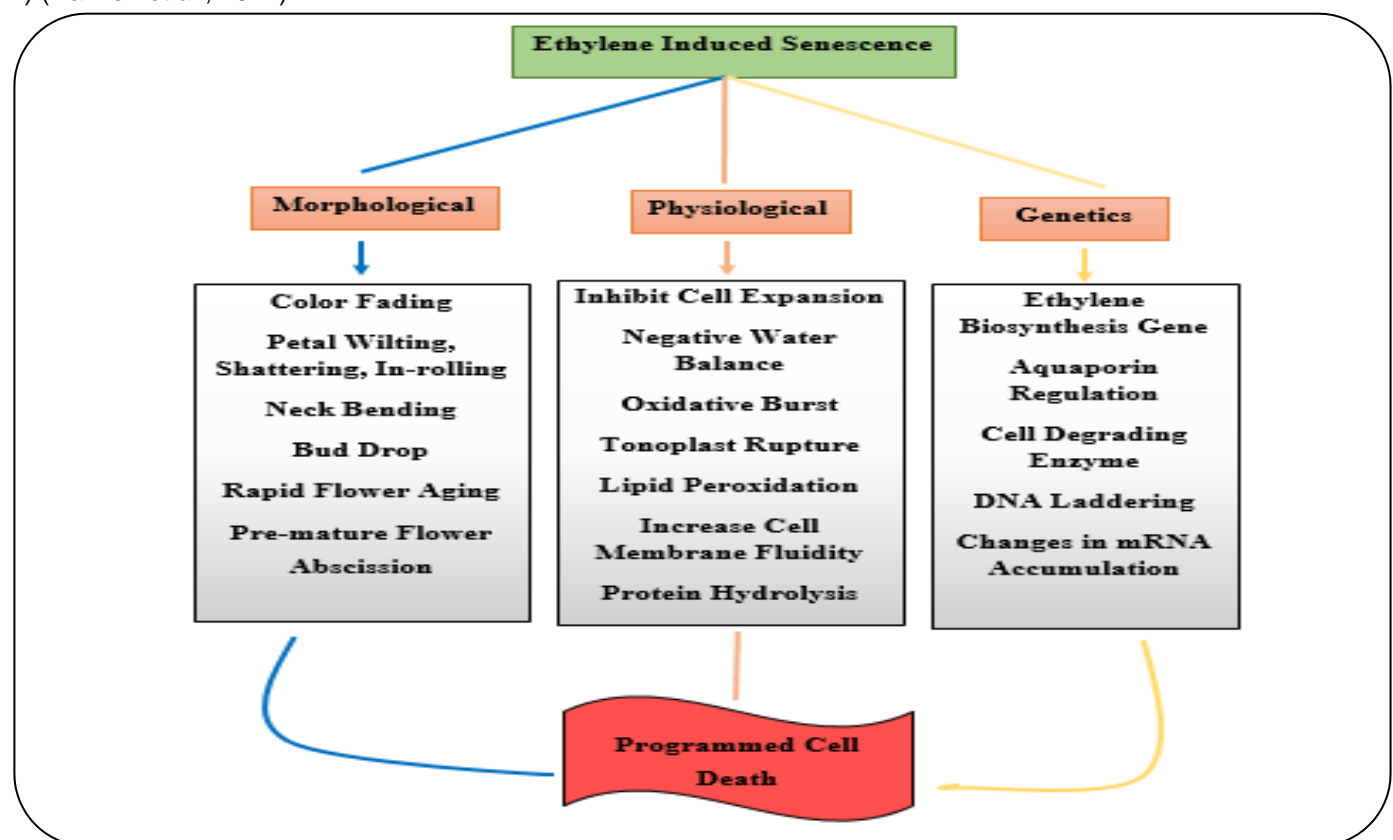


Figure 1. Ethylene induced flower senescence occur at different rate in different flower organs. It has ten cut flower aging by initiating mechanism collectively at morphological, physiological/biochemical and gene level hence altering cellular biochemistry and premature cell death.

Cut flowers are categorized as climacteric and non-climacteric basis on ethylene regulation to flower senescence (Wongjunta et al., 2021). In ethylene independent flower senescence (non-climacteric), ethylene has minimal role in triggering senescence, while in climacteric flowers, ethylene burst along with respiration hastens petal senescence causing them to wither while still attached to flower (Dar et al., 2021; Wu et al., 2017). In ethylene independent senescence, little to minute amount of ethylene is produced by flower during senescence (Shibuya, 2018) and main reason of their senescence and petal abscission is water stress (Wang et al., 2020b). Approximately 93 flower species belonging to different families (Labiate, Roseaceae, and Ranunculaceae) are considered as ethylene sensitive (Kasim and Kasim, 2015). Rose, lily and carnation are top demanded flowers in world however they are highly ethylene sensitive and can last only 5-10 days depending on environmental conditions (Ha and In, 2023). Other than these flowers, Sweet pea, Japanese morning glory, Petunia, Eustoma, Canterbury bells, Snapdragon, Tuberose, Narcissus are also ethylene sensitive crops and endogenous ethylene production rises during senescence time (Azuma et al., 2020; Kato et al., 2022; Kumar et al., 2022; Bayat and Moradinezhad, 2020). In highly sensitive flowers such as orchid and carnation, even lowest concentration can exceed senescence (Naing et al., 2022). As carnation is highly sensitive to postharvest ethylene damage, it is considered as an excellent model for study of ethylene regulation. Ethylene induced flower abscission and senescence is lined with increased expression of ethylene biosynthesis genes. In a study conducted by Wang et al. (2023), postharvest exogenous ethylene exposure increase transcript level of *DcACS1* and *DcAC01* up to 1049 and 1936 times in highly sensitive ethylene cultivars. Moreover, petal senescence in carnation in addition with these genes also associated with petal senescence related genes *CP1* (Naing et al., 2021).

Ethylene role in flower senescence

Generally in ethylene dependent species, a rise in endogenous ethylene production initiate petal senescence, while an exposure to exogenous ethylene further accelerate senescence. Ethylene biosynthesis gene expression is negatively correlated with flower vase life (Wang et al., 2020b). Endogenous ethylene production also accompany with increase in reactive oxygen species and free radicals leading to oxidative stress (Kwon et al., 2024). Ethylene also an important role in biochemical pathway related to cellular breakdown i.e, lipid peroxidation: involved in petal loss, thus affecting commercial aesthetic of cut flowers (Hajizadeh et al., 2024). Overall, ethylene in a form of gas, easily penetrates in flower tissues and affects quality. Moreover they quickly bind with ethylene receptor sites and alter cellular biochemistry (Naghiloo et al., 2019).

In natural conditions, ethylene is constantly producing at low concentration (0.1 $\mu\text{L/kg h}$) to complete various metabolic process in plants. However conditions such as mechanical damage to tissues, pollination, disease, unfavorable temperature or placement of cut flowers in confined or modified environment like green houses or storage areas having high concentration of exogenous ethylene generated by plants, microbial activity, industrial process and combustion significantly accelerates senescence in cut flowers (Mahmoudian et al., 2023). Under such stress environment ethylene biosynthesis increase in specific plant tissues that initiate ethylene signaling pathway that amplify as autocatalytic reaction progress (Olsen et al., 2015; Pérez-Arias et al., 2019). During senescence, ethylene production not only increases insignificantly but flower sensitivity to ethylene also increases as they age (Figure 2) (Williamson and Joyce, 2013).

Ethylene sensitivity and its reduction is an important factor in long term storage of cut flowers (Almasi et al., 2019). Genetic, environmental and chemical applied techniques were employed to limit ethylene synthesis, control ethylene action and to delay flower senescence (Zeng et al., 2023). Application of synthetic ethylene inhibitor is the most common technique employed to delay metabolic rate of climacteric flowers (Lezoul et al., 2022). Various inhibitors were produced and utilized commercially to mitigate the deleterious effect of ethylene and to improve vase life of cut flowers (Wongjunta et al., 2021). Ethylene biosynthesis inhibitors can minimize the premature flower senescence in response to endogenous ethylene production (Finger et al., 2016). They reduced ethylene biosynthesis by blocking components involved in pathway of synthesis. These inhibitors used antagonistic molecules to bind with ethylene receptors thus inhibiting downstream signaling (Costa et al., 2020).

Ethylene inhibitors

Ethylene inhibitors or antagonists are classified into two groups. 1) One that interfere with ethylene synthesis process (chelators, AOA, AVG). 2) Action inhibitors, that works by preventing ethylene signaling (Schaller and Binder, 2017) (Table 1). A single application/exposure of plant tissues to this inhibitors are enough to inhibit ethylene action as they bind for a long time period, saturating receptors in a way that even high concentration of exogenous ethylene can't impart any senescence process. (Ebrahimzadeh et al., 2008). Inhibitor of ethylene biosynthesis and action must be

applied to climacteric species immediately after harvest or before shipping and storage (Finger et al., 2016). This is usually the most common defence practice carried out by growers immediately after harvest to preserve flower quality (Ebrahimzadeh et al., 2008). Addition of ethylene inhibitor chemicals in holding solution protects cut flower against exogenous ethylene (Vijayalaxmi et al., 2022).

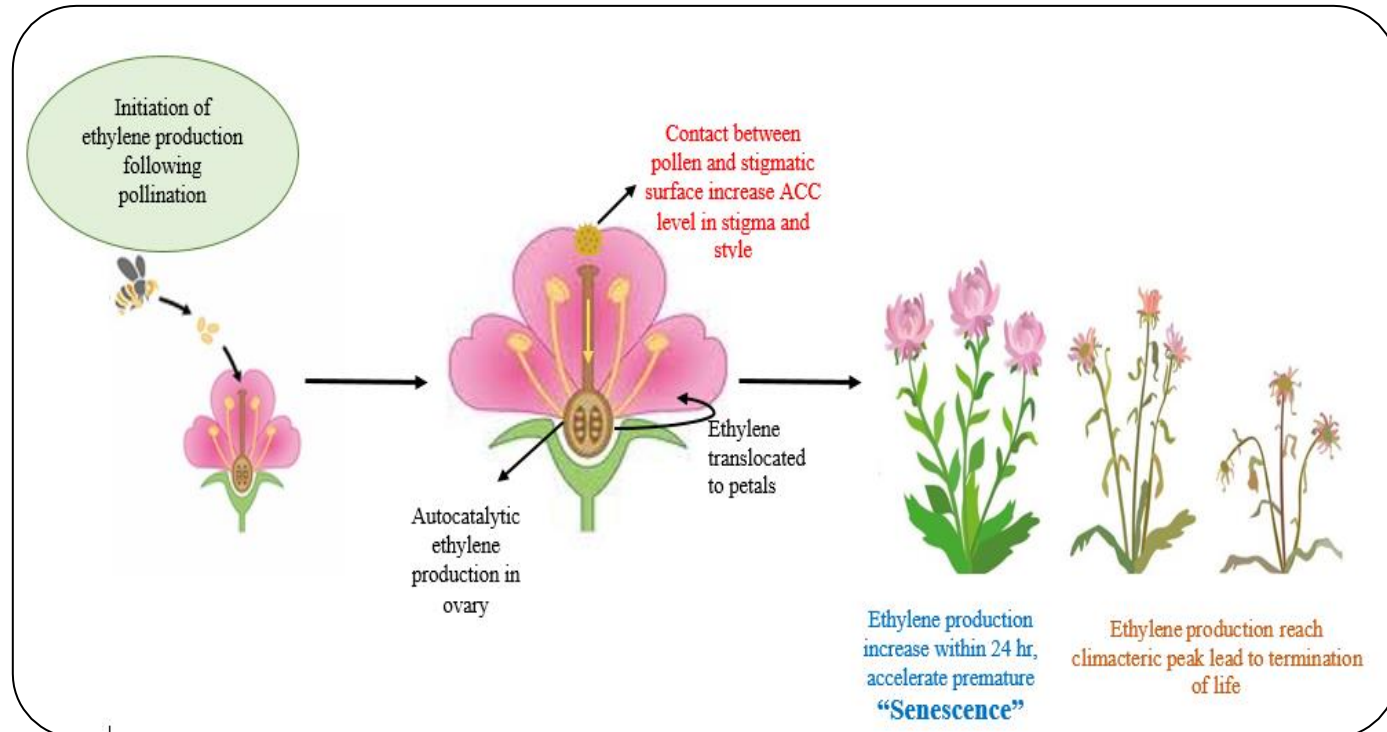


Figure 2. In ethylene sensitive cut flowers, ethylene biosynthesis initiated after pollination. Landing of compatible pollen (contain endogenous ACC content) on stigma surface release signals, increasing ethylene biosynthesis gene expression in pistil particularly in ovary within 1-24 hr after pollination depending on species. Once endogenous ethylene biosynthesis process in initiated it becomes autocatalytic and progress towards senescence (aging, wilting, abscission) of floral parts that are no longer needed i.e, petals. Uncontrolled ethylene production causes flower color fading, petal abscission, premature wilting and leaf yellowing.

Ethylene biosynthesis inhibitor

Ethylene biosynthesis inhibitors works by inhibiting ethylene synthesis enzyme activities. Although these compounds are effective in prevention of ethylene biosynthesis but their practical application are now limited due to cost, toxicity, application efficiency and most importantly their inability to protect cut flowers from exogenous ethylene present in storage environment (Ebrahimzadeh et al., 2008).

Nitric oxide (NO)

Nitric oxide, a lipophilic free unstable gas radical, has high affinity for lipids means it can easily penetrate in watery interior (cytoplasm) and membrane of the cells (Sadeghi and Jabbarzadeh, 2025). NO involved in series of plant processes including development of flower and fruit, regulation of plant maturation, abiotic stresses, enhancing plant immunity and reducing senescence by down regulating endogenous ethylene production (Mittal et al., 2021). Due to it eco-friendly nature, NO is considered as an innovative alternate to hazardous silver related compounds (Farooq et al., 2024).

Sodium nitroprusside (SNP) is the most common NO releasing compound, utilized to prolonged vase life of various cut flowers. SNP promote postharvest life of gaint larkspur (*Consolida ajacis*) by increasing antioxidant enzymes activity with improvement in membrane stability. Moreover, SNP also increases sugar content in petal tissues which is correlated with delay in ethylene biosynthesis (Haq et al., 2023). While SNP application in holding solution improve relative water content, total soluble sugar and proteins while maintaining membrane stability index of gladiolus petal (Mittal et al., 2021). SNP application prevent membrane damage in alstroemeria by reducing lipid peroxidation and improve vase life up to 16 days (Sadeghi and Jabbarzadeh, 2025). Placing of Dendrobium inflorescence in holding solution containing $10 \mu\text{mol L}^{-1}$ promote bud opening and prolonged vase life for 4 days (Mohammadpour et al., 2025). Pulsing of dahlia (*Dahlia pinnata*) stem with SNP solution prevents anthocyanin degradation with an increase in membrane stability index (Chauhan et al., 2024) whereas pulsing of tuberose tuberose flower for 48h with SNP solution ($150 \mu\text{M}$) reduced electrolyte leakage, chlorophyll degradation and melonaldehyde accumulation in

polianthes flower petals (Mohammadi et al., 2024). SNP alleviates oxidative stress and enhanced total phenols, sugar and soluble protein content in tissues of snapdragon (*Antirrhinum majus*) (Farooq et al., 2024).

Table 1: Ethylene inhibitors and their mode of action.

Inhibitors	Formula	Mode of Action	Reference
8-hydroxyquinoline sulfate (8-HQS)	$(C_9H_7NO)_2 \cdot H_2SO_4$	Prevent ACC (1-aminocyclopropane-1-carboxylic acid) enzyme activity	Elgimabi and Sliai, (2013)
Nitric oxide (NO)	NO	Down regulating ethylene emission by decreasing ACO activity (1-aminocyclopropane-1-carboxylate oxidase) activity	Liao et al. (2013)
2-Aminoxyisobutyric acid (AOIB)	$C_4H_9NO_2$	Inhibit ACC synthase and oxidase activity	Kosougi et al. (2014)
Sucrose	$C_{12}H_{22}O_{11}$		Wang et al. (2014)
Ethanol	C_2H_6O	Limit ACC synthase action	Sakr et al. (2016)
α -Aminoisobutyric acid (AIB)	$C_4H_9NO_2$	Inhibit ACO activity	Ha et al. (2019)
Silver (Ag)	Ag+	Decrease number of actively binding site Silver replacement with copper at receptor site	Hoppen et al. (2019) Sedaghathoor et al., (2020).
1-Methylcyclopropene (1-MCP)	C_4H_6	Bind to ethylene receptors irreversibly, block signal transduction	Azuma et al. (2020)
2,5-Norbornadien (2,5-NBD)	C_7H_8	Binding to ethylene receptors	Costa et al. (2020).
Aminoethoxyvinylglycine (AVG)	$C_6H_{12}N_2O_3$	Delays synthesis of ACC Binds and inactivates structure of ACS	Gun, (2020) Ha et al. (2020)
Sodium nitroprusside (SNP)	$Na_2[Fe(CN)_5NO]$	Suppressing ACC synthase activity	Hasssan et al. (2020)
2,4-pyridinedicarboxylic acid (2,4-PDCA)	$C_7H_5NO_4$	Inhibit ACC oxidase activity	Satoh et al. (2020)
Aminoxyacetic acid (AOA)	$C_2H_5NO_3$	Prevent conversion of SAM to ACC Reduce amount of substrate for ACC oxidase	Costa et al. (2020) Costa et al. (2021)
Epibrasinolide (EBL)	$C_{28}H_{48}O_6$	Decrease ACC oxidase and ACC gene expression	Darvish et al. (2021)
Boric acid (BA)	H_3BO_3	Inhibiting ACC oxidase and synthase activity	Farooq et al. (2021)
Salicylic acid	$C_7H_6O_3$	Block ACC conversion to ethylene Inactivate ACC oxidase enzyme	Nisar et al. (2021) Khandan-Mirkohi et al. (2021)
Nano silver (NS)	AgNPs	Inhibiting mRNA level of ethylene biosynthesis genes Replacing copper ions with silver ions at binding site	Ha et al. (2021) Ha and In (2023)
Benzyl adenine (BA)	$C_{12}H_{11}N_5$	Inhibit ACC accumulation in petals	Etemadypoor et al. (2023)

Effectiveness of NO application is based on plant species and concentration. High concentration increase oxidative stress through a process called nitrostress, destroying cellular components (Sadeghi and Jabbarzadeh, 2025). NO at high doses produces peroxynitrite (ONOO) radical, damaging macromolecules and accelerates aging process in cut flowers (Moghaddam et al., 2021).

Sugar

Sugars are an important precursor of respiration in cut flowers (Hussen and Yassin, 2013). It also has a role in maintenance of osmotic pressure in cells (Wang et al., 2014). Various sugar types like glucose, sucrose and fructose can be used as an energy source but among them sucrose is the most common carbohydrate used in vase solution (Sales et al., 2018). Addition of sugar in preservation solution reduced flower sensitivity to ethylene. It antagonized the inhibitory effect of abscisic acid, maintain mitochondrial structure and improve its function (Chandran et al., 2006). Sugar in vase solution significantly enhance shelf life by supplying respiratory substrates, carbohydrates, osmolytes and structural constituents (Dar et al., 2021). According to conducted research, sugars interaction with ethylene signaling and biosynthesis delays flower senescence in ethylene sensitive species due to regulated changes in mRNA accumulation (Wang et al., 2014). Maintaining a sugar level in flower petals reduced climacteric increase in ethylene (Zeng et al., 2023). It was reported that sucrose inhibit ethylene synthesis signaling more efficiently than STS as expression of senescence related gene *Dc-EIL3* was delayed by STS but completely prevented by sucrose application (Tripathi and Tuteja, 2007).

Sucrose 5% along with AVG treatment delayed transcription level of *DcASC1* and *DcAC01* thus limiting climacteric increase in endogenous ethylene production (Pun et al., 2016). Similar results were obtained by Kondo et al. (2020) who studied that petal senescence in cut carnation is accelerated due to decrease in sugar content in petals (sugar starvation) as fructose and glucose level continuous decrease in cut petals hasten senescence (petal in rolling). As sucrose treatment not only suppress expression of *DcASC1* and *DcAC01* gene involved in ethylene biosynthesis but also delayed activity of ACS and ACO. Sucrose in holding solution prevent protein degradation in petals of clematis (*Clematis terniflora*) by limiting cysteine protease activity (Rabiza-Swider et al., 2019). Reduction in lipid peroxidation with enhanced ROS scavenging activities by sucrose, promotes vase life of cut lily stems (Zeng et al., 2023). Glucose prolongs vase life of peony (*Paeonia suffruticosa*) by delaying activity of ACC synthase and suppression of ACC oxidase in petals protecting flower from climacteric increase of ethylene (Wang et al., 2014). Placement of Dendrobium stems in solution of sucrose 4%+ 0.5 mM AOA prevent flower petals thinning, color fading and hyponasty (Chandran et al., 2006).

Rhizobitoxin analogs

Rhizobitoxin, a phytotoxin produced by bacteria has a role in reducing ethylene production by inhibiting ACC synthase activity. Hence a closely related analogs of rhizobitoxin AOA and AVG inhibit ethylene synthesis (Sugawara et al., 2006). AOA (Amino-oxyacetic acid) and AVG (2-aminoethoxyvinyl glycine) inhibit ethylene synthesis in climacteric flowers by reducing pyridoxal enzyme activity- an important cofactor that converts S-adenosyl-l-methionine to ACC (Naghiloo et al., 2019; Costa et al., 2021). Both compounds AVG and AOA are not as effective as STS or 1-MCP due to their inability to completely protect flowers from ethylene, as it can still bind to receptor sites even after application of AVG and AOA (Finger et al., 2016). Moreover, both AOA and AVG could minimize endogenous ethylene production but they are ineffective for exogenous ethylene exposed by flower during postharvest handling, transportation and storage process (Kasim and Kasim, 2015).

AOA treatment not only limit ACS gene activity in alstroemeria flower but also increase peroxidase and catalase enzyme activity that reduced cell degradation and improve relative water content in cells (Naghiloo et al., 2019). Floret senescence rate delayed in Mokara cut orchid when cut stem were pulsed with AOA for 24 hr (Wongjunta et al., 2021). It binds with ethylene receptors as low as 0.2 μL^{-1} to 1 μL^{-1} concentration (Costa et al., 2021). AOA treatment extend vase life of chrysanthemum by improving membrane stability, stabilize chlorophyll content and reduced TSS and reducing sugar content in petals (Kumari et al., 2016). Combined application of AVG+NS improve vase life of rose and carnation by reducing expression of senescence associated genes (*DcCP1* and *RhSIG*) and mRNA expression of ACS, ACO1 genes (Ha and In, 2023). Sucrose 5% along with AVG treatment delayed transcription level of *DcASC1* and *DcAC01* thus limiting climacteric increase in endogenous ethylene production (Pun et al., 2016). Leaf chlorophyll content, fresh weight and petal color of cut ranunculus flower improved by application of AOA (Scariot et al., 2009). As AOA is nonspecific ethylene inhibitor that works by forming complex with cofactor pyridoxal phosphate, hence it may interfere with other enzymatic reactions, affecting physiological process in plants (Alonso-Salinas et al., 2024).

In an experiment on improving quality of cut *Eustoma (Eustoma russellianum)* flowers, it was studied that when AVG was combined with NAA there was 3-fold increase in vase life of inflorescence along with an increase in relative fresh weight (Shimizu-Yumoto and Ichimura, 2010). AVG at concentration of 10ppm improves vase life, total water uptake and fresh weight of narcissus (Gun, 2020). Application of both 1-MCP and AVG to rose cultivars completely prevent petal abscission along with improvement in Chlorophyll fluorescence ratio in leaves leading to reduction in water stress (Ha et al., 2020). Treatment of crucifix orchid (*Epidendrum ibaguense*) cut stems with AVG reduced flower abscission up to 71% while increased flower longevity to 76% as compared to control (Moura et al., 2010). However, both chemicals are very expensive, therefore limiting their application in floriculture industry (Rani and Singh, 2014). Moreover, pungent smell of AOA render it unacceptable for practical use (Zeng et al., 2012) while AVG is difficult to prepare (Kasim and Kasim, 2015).

ACC analogues

Treatment of structural analogues of enzymes substrates involved in hormone synthesis is an efficient technique to regulate hormone activity (Li et al., 2023). AIB (Amino isobutyric acid) is a structural analogue of ACC and work as ethylene antagonist by inhibiting ACC oxidase activity. AIB in combination with nano silver and 1-MCP delays early wilting and reduced water uptake in cut roses by regulating expression of water transport genes (Ha and In, 2022). A preservative solution CIAM consisting of 1-MCP, sodium hypochlorite and AIB inhibited petal senescence in cut rose flower by suppressing *RhACO1* and *RhACS2* transcripts levels and extend vase life up to 4.3 days (Ha et al., 2019). Furthermore, AIB application increase flower opening percentage, delayed petal wilting and prolonged vase life of fringed pink (*Dianthus superbus*) (Satoh et al., 2008).

Another compound, 2-Aminooxyisobutyric acid (AOIB) is analogue of both AIB and AOA, It resembles AIB in tetrahedral structure while its partial structure is similar to AOA in its whole structure. Thus it works by inhibiting both ACC oxidase and synthase activity. AOIB partially similar to the structure of AOA, inhibit and prolonged vase life of carnation up to 7 days (Kosougi et al., 2014).

Ascorbate analog: 2,4-Pyridinedicarboxylic acid (24PDCA)

2,4-PDCA reduced ethylene biosynthesis by inhibiting activity of ACC oxidase by competing with ascorbate: a co-substrate in his enzymatic reaction (Satoh and Nomura et al., 2019). Ethylene inhibitor (PDCA) analogues (2,4-PDCA) shorten the time of flower opening in cut carnation (*Dianthus caryophyllus*) by accelerating bud opening percentage (Sugiyama and Satoh, 2015). Pulsing of cut carnation stem with 10 mM 2,4-PDCA solution prolonged vase life upto 11 days as compared to control (5 days) (Satoh et al., 2016). It also reduces petal blackening in lotus cut flower (*Nelumbo nucifera*) by limiting respiration rate and ethylene production (Salaemae et al., 2018).

Boric acid

When plant respire, the activity of ACC (aminocyclopropnae-1-carboxylic acid) synthase and ACC oxidase increase which converts SAM (S-adenosyl-methionine) into ACC and from ACC to ethylene. Boric acid limit ethylene production by reducing the activity of ACC synthase and oxidase (Kshirsagar et al., 2021). Boric acid is an excellent substitute to toxic ethylene antagonists as it is biodegradable, inexpensive and non-toxic in nature (Farooq et al., 2021). Boric acid delays chlorophyll degradation in cut roses (*Rosa hybrida*) and reduced the production of ABA in petals due to anti-ethylene property (Hashemabadi et al., 2014). Senescence in jasmine cut flowers (*Jasminum nitidum*) was delayed by boric acid through increasing total phenolic content in flower petals (Manimaran et al., 2018). It increases petal protein content and brix in carnation (*Dianthus caryophyllus*) (Ahmadnia et al., 2013) and attained higher freshness index in tuberose (*Polianthes tuberosa*) cut flower (Khongwir et al., 2017). Pulsing solution containing mixture of chemicals (Boric acid + 8-HQC+ Sucrose + AOA) significantly preserve carbohydrate content, maintained water balance and enhanced water uptake in carnation (Sarhan et al., 2023). While its application prevent foxglove (*Digitalis purpurea*) flower degradation by increasing antioxidant enzyme activities (LOX, CAT, APX, SOD) with an increase in flower diameter and vase life (Farooq et al., 2021). Moreover, boric acid in combination with AgNO₃ and sucrose decrease days to require 1st petal spreading of rose with maximum flower fresh weight at senescence (Kshirsagar et al., 2021).

Cobalt

Cobalt in a form of cobalt chloride improve vase life of different ornamental plants by inhibiting ethylene synthesis, microbial proliferation, vascular blockage and stomatal closure under stress condition (Azarhoosh et al., 2021). By inhibiting ethylene biosynthesis enzymes (ACC oxidase) activity, cobalt chloride improving membrane stability in liliium (Kazemi and Ameri, 2012) and improve total and reducing sugar in chrysanthemum petals (Amin, 2017). Cobalt chloride in combination with sucrose increased flower diameter, number of blooms per scape and pigment content in

petals of day lily (*Hemerocallis fulva*) (Arief and Tahir, 2015). Its application as preservative solution maintained high water flow rate in cut stems of rose by inhibiting vascular blockage (Aslmoshtaghi et al., 2018). In tuberose (*Polianthes tuberosa*), it enhanced the vase life by increasing vase water absorption and petal protein content (Mohammadi et al., 2012) and minimize transpiration loss in carnation (Priyanka et al., 2024).

Alcohol

Ethanol is known as anti-ethylene compound which not only limit the ethylene enzyme activity but also reduce vascular blockage and delays leaf chlorosis (Sasikala et al., 2015). Preservative solution consisting of ethanol, sucrose and aluminium sulphate significantly maximize solution uptake, petal fresh weight, flower diameter, TSS (Brix^o) and vase life of different rose cultivars (*Rosa hybrida*) (Gebremedhin et al., 2013). Ethanol in combination with malic acid prevent oxidative stress in carnation (*Dianthus caryophyllus*) by reducing production of MDA content. Due to its ability to increase metabolism level, it decreased the dry weight and also caused reduction in fresh weight loss (Begri et al., 2014). As ethanol also work against stress caused by water deficiency, it improved foliage color of amaranthus (*Amaranthus tricolor*) cv. Red and Burgundy and increased stomatal conductance to improved solution uptake and its assimilation (Piechocki and Salachna, 2019). Ethanol along with sucrose decreased α -amylase and peroxidase activity and reduce starch content in petals of feverfew flower (*Matricaria parthenium*) (Kaur and Mukharjee, 2012). Due to its anti-ethylene properties, ethanol preserve chlorophyll contents in Alstroemeria flowers by developing chloroplast and inhibiting chlorophyllase enzyme activity (Kiaseh and Yadegari, 2016).

Methanol maintained moisture content and enlarged chrysanthemum (*Chrysanthemum morifolium*) flower size by increasing superoxide dismutase (SOD) activity along with reducing lipoxygenase (LOX) and protease enzymes activity (Khokhar and Mukherjee, 2013). Moreover, it also improved water balance in chrysanthemum (*Chrysanthemum morifolium*) cut stems at 4% concentration (Bazaz et al., 2015). Methanol as a preservative solution improves solution uptake and delays drying of carnation petals (*Dianthus caryophyllus*) and even reduced the folding of petals from the tips (Kaur and Mukherjee, 2013).

Different alcohols have a role in prolonging postharvest life cut carnation (*Dianthus caryophyllus*). Propanol at 2 and 4% reduced protein degradation, improved chlorophyll content and vase life. Whereas bentanol was effective in inhibiting ethylene synthesis and pentanol minimize loss in fresh weight (Bagheri et al., 2015).

Benzyladenine

Cytokinins improves the vase life by increasing the integrity of tonoplast (a membrane surrounding the vacuole), reduce the leakage of proteases enzymes to prevent hydrolysis of soluble proteins present in mitochondrial and chloroplast membrane. Moreover, it delays the senescence by reducing chlorophyll degradation and increasing chlorophyll activity (Wijayabandara et al., 2018). Thus an application of BA, a synthetic cytokinin improve vase life of dahlia florets effectively in comparison to other ethylene inhibitors (STS, 1-MCP) (Shimizu-Yumoto and Ichimura, 2013). Combined action of BA and 1-MCP slows down rose senescence by decreasing endoproteases enzyme activity and proline contents (Farazmandi et al., 2020). Application of BA (Benzyladenine) application at 25 and 50 mg/L not only reduced autocatalytic ethylene biosynthesis reaction but also preserve anthocyanin degradation thus maintaining color of Eustoma cut flower (Asil and Karimi, 2010). It also increase vase life of carnation by increasing petal sugar content, photosynthetic pigments and flower diameter (Etemadypoor et al., 2023). BA application to stems of Siam tulip (*Curcuma alismatifolia*) affect expression of senescence related genes, increase antioxidant enzymes activity and reduced jasmonic acid biosynthesis (Zhou et al., 2023).

Ethylene action inhibitor

These inhibitors works by binding with ethylene receptors to avoid ethylene binding, hence prevent ethylene action. Moreover, they protect flower from both endogenous and exogenous ethylene and prevent autocatalytic ethylene synthesis (Ebrahimzadeh et al., 2008). Blocking action of these inhibitors are usually based on competition between hormones and molecules at binding site (Figure 3) (Scariot et al., 2009). Inhibitors such as silver nitrate, 2,5-norbornadiene and 1-methylcyclopentene are active competitor for active site on ethylene receptors but they are no commercially applicable due to offensive smell and toxicity (Devecchi et al., 2009).

Silver

Silver ions has been used for a long time as a potent ethylene inhibitor in floral industry. Diluted solution of silver salts are commercially used to prolonged floral blooms. Silver inhibit ethylene biosynthesis by replacing copper co-factor required for binding site for receptors, altering binding sites to transduce ethylene signals (Schaller and Binder, 2017). As silver has ethylene binding inhibition properties so it reduces the endogenous ethylene production and delays the senescence symptoms such as petal in-rolling, premature wilting and flower bud abscission (Thwala et al., 2013).

Silver nitrate is one of the most common type of silver salts that is used both as a germicide and an ethylene inhibitor in commercial preservative solutions (Khella *et al.*, 2018). This collective action of silver nitrate delays the senescence and reduce the degradation of anti-oxidant compounds like anthocyanin in gerbera (Abadi *et al.*, 2013). Due to ethylene biosynthesis inhibitor, silver nitrate increase tuberose (*Polianthes tuberosa*) flower diameter and length, no of flower open per day and reduced dropping of flowers (Kumari *et al.*, 2018) and it reduce chlorophyll loss and carbohydrate degradation in stems of cut rose (*Rosa hybrida*) (Yagi *et al.*, 2014). Silver nitrate application downregulated of ACO2 gene expression in sweet osmanthus (*Osmanthus fragrans*) (Qiu *et al.*, 2024). Pulsing of liliium stem for 6 h in pulsing solution of silver nitrate+citric acid+ sucrose promotes uniformity in floral opening and enhanced vase life up to 2 days (*Lilium pumilum*) (Krause *et al.*, 2021).

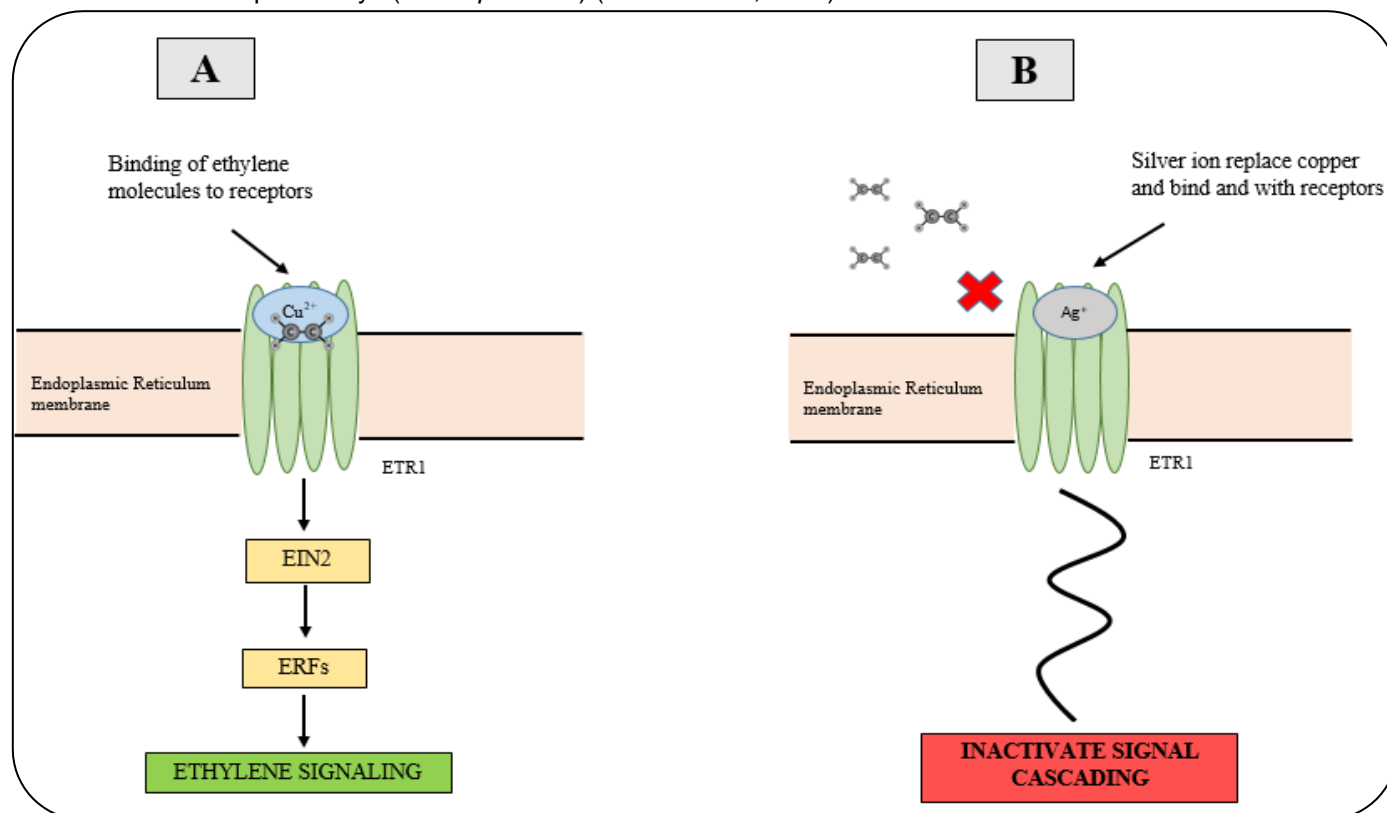


Figure 3. Ethylene action inhibitor working: (A) Under normal environmental conditions, ethylene molecules bind with ethylene receptors (ETR1) located in endoplasmic reticulum membrane using copper ions (Cu^{2+}) as co-factor. Binding with receptors enhance enzymes activity and activate signal transduction. (B) Ethylene action inhibitor i.e., AgNO_3 works by replacing copper ions with silver ions thus preventing ethylene molecules binding and block ethylene signaling.

Silver ions preferable in a form of silver thiosulphate (STS) is the most widely used active ingredient to prevent premature aging of cut flowers. Silver acetate and nitrate mobilize slowly in tissues and decompose upon exposure to light, whereas STS readily move towards flower organ thus enhanced vase life (Sedaghatthoor *et al.*, 2020). STS along with inhibiting autocatalytic ethylene production, also decrease the activity of lipoxygenase (Lox) with a decrease in respiration rate (Asrar, 2012; Abou El-Ghait *et al.*, 2012; Begri *et al.*, 2014). STS has high mobility in plant tissue with more stability than silver nitrate and less phototoxic and more effectiveness at low concentration (Costa *et al.*, 2021). Due to reduction in cellular respiration, STS application along with sucrose improve fresh weight and water relation of gerbera flowers (Vijayalaxmi *et al.*, 2022) and increase sugar content in foxglove (*Digitalis purpurea*) by slowing down cellular respiration (Farooq *et al.*, 2022). In rose (*Rosa hybrida*), STS improve vase life, increase flower diameter, preserved carbohydrate content and prevent petal abscission (Ha *et al.*, 2017) while in gladiolus spikes (*Gladiolus grandiflorus*), it prolonged time required to senescence basal floret (Uddin *et al.*, 2016). Whereas STS increased total carbohydrate percentage and pigment contents in cut limonium (*Limonium sinuatum*) flowers (Khella *et al.*, 2018). Moreover, It promote the longevity of clarkia (*Clarkia pulchella* and *Clarkia amoena*) flower by enhancing intervase activity and decreasing activity of lipoxygenase, lipid peroxidation and total phenols content thus improving membrane stability (Arief, 2016; Dar and Tahir, 2018). Ethylene minimize the intervase activity

(availability of sugar to developing buds) in cut flowers, therefore application of STS (0.5 Mm) increase availability of respirable sugar to developing bud thus prolonged vase life of clarkia flowers (Arief et al., 2016).

Despite its effectiveness, silver has toxic effect to environment and human health. Hence, to prevent the harmful effects of these hazardous compounds, there is rise in demand for usage of safe compounds as ethylene inhibitor (Nasiri et al., 2020). A safe alternative, silver nanoparticles also reported to inhibit ethylene synthesis in cut flower by suppressing ethylene biosynthesis gene expression. Nano silver treatment prolonged vase life of peony flower by inhibited ethylene release by 40.9% through reduced activity of ACS and ACC, whereas increase content of succinic dehydrogenase (SDH), sugar and H⁺-ATPase thus maintaining high energy charge (Yi et al., 2018). Moreover, nano silver also work as ethylene inhibitor by preventing expression of important regulators in ethylene signal transduction pathway (*EBF1*, *ERS2* and *EIL1*) while suppression expression of ethylene biosynthesis gene (Naing et al., 2021). Silver nanoparticle application inhibit carotenoids and anthocyanin degradation in petals of chrysanthemum hence add an increment of 4 days in vase life (Prabawati et al., 2023).

Cyclic olefins

In 1970s, cyclic olefins were discovered as an important compounds used to antagonize ethylene action by irreversibly binding to receptors protein (Choi et al., 2023). Many compounds in this group i.e, 2,5-norbornadiene (2,5-NBD), *cis*-butene, *trans*-cyclootene, 1-methylcyclopropane (1-MCP), Diazocyclopentadiene (DACP), 3,3-Dimethylcyclopropene (3,3-DMCP), cyclopropenes [1-octylcyclopropene (1-OCP), 1-hexylcyclopropene (1-HCP)] were identified as ethylene action blocker (Sisler and Serek, 1999; Sisler and Serek, 2003; Serek et al., 2006). However, except for 1-MCP, other compounds are not commercially utilized presently and considered unfit to be use as preservative solution due to their explosive nature, foul odor and ineffectiveness (required continuous exposure) (Sisler and Serek, 1999). Whereas, 1-MCP has been available for commercial use since 2000 under trade name of EthylBloc. It is known as an effective ethylene inhibitor as it is stable at room temperature, have no detectable odor and non-toxic to environment (Serek et al., 2006).

1-Methylcyclopropane (1-MCP)

Need of an alternative material, free from heavy metals leads to the discovery of 1-MCP (Scariot et al., 2009). 1-methylcyclopropane discovered in 1995, is the first non-potent ethylene inhibitor available in gaseous form (Scariot et al., 2014). It inhibit ethylene synthesis by binding itself to hormone receptors in an irreversible way. The affinity of 1-MCP to bind with receptors is ten times greater than ethylene (Cavallaro et al., 2023). Lower effective concentration with minimum residue makes it an ideal substitute for toxic chemicals. Binding of 1-MCP with ethylene receptor inactivates ethylene autocatalytic reaction and protects cut flower from both endogenous and exogenous ethylene (Almasi et al., 2019).

1-MCP inhibit ethylene action in wintersweet flower (*Chimonanthus praecox*) by reducing the expression of *CpSRG1* gene (senescence causing gene) and improve vase life up to 2.1 days (Sui et al., 2015). Pulsing of viburnum (*Viburnum tinus*) stems with 1-MCP causes an extension of 4.5 days in vase life as compared to control along with reduction in flower abscission rate and respiration rate respectively (Darass et al., 2010). Its use as preservative solution minimize electrolyte leakage in petals of gerbera (*Gerbera jamesonii*) (Nazari and Saba, 2017), retard carbohydrate and chlorophyll degradation in rose (*Rosa hybrida*) (Hassan, 2016) and reduce weight loss (%) in carnation (*Dianthus caryophyllus*) (Asil et al., 2013). Preservative solution having composition of CIAM (1-MCP + aminoisobutyric acid + sodium hypochlorite) improved solution uptake, inhibited bacterial growth in cut end of rose (*Rosa hybrida*) stem. Furthermore, expression of ethylene synthesis genes (*RhACO1*) and (*RhACS2*) were also surpassed by CIAM preservative solution (Ha et al., 2019). 1-MCP significantly delayed petal senescence of highly ethylene sensitive dahlia varieties (Azuma et al., 2020), minimize flower fresh weight reduction, delay deterioration and reduced ethylene production from gerbera flower head (Hongpakdee et al., 2022).

It blocks downstream transduction and inhibited expression of genes induced by ethylene hence extend vase life of *Alestromeria* by increasing protein content and reducing damage by ROS through initiation of antioxidant enzyme activities (Nasiri et al., 2020). 1-MCP treatment with selenium reduced postharvest metabolism of narcissus by lowering climacteric respiration rise with improvement in scavenging activities (Bayat and Moradinezhad, 2020). 1-MCP application at 0.5-1.0 $\mu\text{L L}^{-1}$ improves water balance, water uptake rate and fresh weight of foxtail cut flower (*E. spectabilis* and *E. persicus*) but also extend vase life up to 2 more days as compared to control (Mahmoudian et al., 2023). Combined application of 1-MCP+TDZ (Thidiazuron) not only prolonged vase life up to 4 days but also minimize chlorophyll degradation and weight loss of ranunculus flower (Cavallaro et al., 2023). Pretreatment of cut vanda blue orchid flowers for 6 hr prevent ethylene induced color fading and prevent anthocyanin degradation by

recovering inflorescence color (Khunmuang et al., 2019). However, several complications are associated with 1-MCP due to its gaseous nature, thus a new initiative: a and B cyclodextrin based nanosponges 1-MCP complex reduced ethylene production in carnation and retain petal color for longer time (Seglie et al., 2011). Despite its effectiveness, its inhibiting effect is for limited time period which usually depends upon flower stage and ethylene sensitivity of a specie (Ha et al., 2020).

Synthetic peptides

Peptides proved to have an important role in plant development and response towards environmental stresses. In contrast to natural peptides, synthetic peptides can alter plant signaling by interfering with protein-protein interaction (IPP) in signaling pathway (Hofmann et al., 2021). Synthetic peptide- Oligopeptides (NOP-1) derived from nuclear localized signal (NLS) located at EIN2 C-terminus interferes with protein-protein interaction. It inhibit the interaction between ethylene receptors (ETR1) and ethylene signaling protein, ethylene-insensitive-2 (EIN2) hence inhibit ethylene response (Kessenbrocket al., 2017; Klien et al., 2018).

Peptide NOP-1 significantly delayed vase life of carnation and rose by 6-8 as compared to control due to its ability to bind with ethylene receptors. It has advantage over other chemical inhibitors (Silver and 1-MCP) as it is sustainable, biodegradable and low toxic to environment (Hoppen et al., 2019).

CONCLUSION

Cut flowers are metabolically active after harvest and carried out all life sustaining process by using stored reserves. Their quality, vase life and appearance were depend on growing conditions, harvesting time, environmental factors and postharvest management. Senescence in cut flowers is usually associated with climacteric increase of ethylene production occurs due to carbohydrate depletion, water stress or microbes. Thus, use of ethylene inhibitors to minimize ethylene synthesis is one of the most common, cheapest and safest technique used by growers and florists to preserve vase life after harvest, during transportation and storage. These inhibitors improves flower quality by restricting metabolic activities, maintaining water balance and by reducing oxidative stress.

AUTHOR CONTRIBUTIONS

Ayesha Manzoor: Conceptualization, original draft preparation and writing, Tanveer Hussain and Naeem Akhtar: Proof reading of review paper, Muhammad Waqas Azam and Syed Awais Sajid: Gather research material for review writing, Ahsan Hammad and Tamoor Hussain: Design and constructed Table 1, Muhammad Arslan and Muhammad Saqib Naveed: Design figures and their caption.

COMPETING OF INTEREST

The authors declare no competing interests.

REFERENCES

- Abadi, M., Moghadam, A., Abdossi, V., 2013. The affected postharvest life of gerbera cut flowers by the application of silver nitrate, silver thiosulfate and nano silver. *International Research Journal of Applied and Basic Sciences*, 4: 806-809.
- Abou., El-Ghait, E.M., Gomaa, A.O., Youssef, A.S.M., Mohamed, Y.F., 2012. Effect of some postharvest treatments on vase life and quality of chrysanthemum (*Dendranthema grandiflorum* Kitam) cut flowers. *Research Journal of Agriculture and Biological Sciences*, 8(2): 261-271.
- Ahmadnia, S., Hashemabadi, D., Sedaghatthoor, S., 2013. Effects of boric acid on postharvest characteristics of cut carnation (*Dianthus caryophyllus* L. cv.'Nelson'). *Annals of Biological Research*, 4(1): 242-245.
- Almasi, P., Mohamed, M. T. M., Ahmad, S. H., Noroozisharaf, A., 2019. Efficacy of 1-MCP on controlling ethylene sensitivity and extending vase life of sensitive and less sensitive cut orchid flowers. *Fundamental and Applied Agriculture*, 4(2): 759-768.
- Alonso-Salinas, R., López-Miranda, S., Pérez-López, A. J., Acosta-Motos, J. R., 2024. Strategies to delay ethylene-mediated ripening in climacteric fruits: Implications for shelf life extension and postharvest quality. *Horticulturae*, 10(8): 840.
- Amin, O. A., 2017. Effect of some chemical treatments on keeping quality and vase life of cut chrysanthemum flowers. *Middle East Journal of Agricultural Research*, 6(1): 208-220.
- Arief Z. M., 2016. Defoliation and silverthiosulphate pulse treatment prolongs the vase life of cut stalks of *Clarkia amoena*. *Journal of Plant Science and Research*, 3(2): 162-164.
- Arief Z.M., Tahir I., 2015. Sucrose, cobalt chloride and aerated soft drink improves the vase life and quality of cut scapes of *Hemerocallis fulva*. *Journal of Postharvest Technology*, 3(4): 97-100.

- Asil, H.M., Karimi, M., 2010. Efficiency of benzyladenine reduced ethylene production and extended vase life of cut *Eustoma* flowers. *Plant Omics*, 3(6): 199-203.
- Asil, M.H., Karimi, M., Zakizadeh, H., 2013. 1-MCP improves the postharvest quality of cut spray carnation (*Dianthus caryophyllus* L.) 'Optima' flowers. *Horticulture, Environment, and Biotechnology*, 54(1): 58-62.
- Aslmoshtaghi E., Jafari M., Rahemi M., 2018. Effects of daffodil flowers and cobalt chloride on vase life of cut rose. *Journal of Chemical Health Risks*, 4(2): 1-6.
- Asrar A.W.A., 2012. Effects of some preservative solutions on vase life and keeping quality of snapdragon (*Antirrhinum majus* L.) cut flowers. *Journal of the Saudi Society of Agricultural Sciences*, 11(1): 29-35.
- Azarhoosh, J., Hashemabadi, D., Asadpour, L., Kaviani, B., 2021. Extending vase life of cut *Strelitzia reginae* Aiton flowers by cobalt chloride, cerium nitrate, silver nanoparticles and nanosil. *Acta Scientiarum Polonorum Hortorum Cultus*, 20(4): 89-99.
- Azuma, M., Onozaki, T., Ichimura, K., 2020. Difference of ethylene production and response to ethylene in cut flowers of dahlia (*Dahlia variabilis*) cultivars. *Scientia Horticulturae*, 273, 109635.
- Bagheri H., Lotfalizadeh H., Soleimani A.H., 2015. Effect of butanol, propanol and pentanol on the quality of cut Carnation cv. 'Nelson'. *Biharean Biologist*, 9(1): 40-43.
- Bayat, H., Moradinezhad, F., 2020. Extending vase life of *Narcissus tazetta* L. cut flowers using selenium and 1-methylcyclopropene treatments. *Journal of Applied Horticulture*, 22(3): 196-201.
- Bazaz A.M., Tehranifar A., Karizaki A.R., 2015. Use of ethanol, methanol and essential oils to improve vase-life of chrysanthemum cut flowers. *International Research Journal of Applied and Basic Sciences*, 9(8): 1431-1436.
- Begri F., Hadavi E., Nabigol A., 2014. Positive interaction of ethanol with malic acid in postharvest physiology of cut spray carnation 'White Natila'. *Journal of Horticultural Research*, 22(2): 19-30
- Cavallaro, V., Bulgari, R., Florio, F. E., Restuccia, P., Vinci, G., Guffanti, D., ... Ferrante, A., 2023. Postharvest strategies for preventing flower wilting and leaf yellowing in cut *Ranunculus* flowers. *Frontiers in Horticulture*, 2: 1183754.
- Chandran, S., Toh, C.L., Zuliana, R., Yip, Y.K., Nair, H., Boyce, A.N., 2006. Effects of sugars and aminoxyacetic acid on the longevity of pollinated *Dendrobium* (Heang Beauty) flowers. *Journal of Applied Horticulture*, 8: 117-120.
- Chauhan, C., Kumar, M., Rani, V., Singh, R., 2024. Efficacy of postharvest treatments with sodium nitroprusside and gibberellic acid on physio-biochemical modifications and vase life of dahlia cut flower. *South African Journal of Botany*, 174: 580-592.
- Choi, S.J., Ahn, G.H., Lee, K.H., Jahng, W.J., 2023. Synthesis of 1-(2,2-dimethylpropyl)-cyclopropene (1-DCP) as an ethylene antagonist. *ACS omega*, 8(32): 29770-29778.
- Costa, L.C., de Araujo, F.F., Ribeiro, W.S., de Sousa Santos, M.N., Finger, F.L., 2021. Postharvest physiology of cut flowers. *Ornamental Horticulture*, 27(3): 374-385.
- Costa, L.C., Luz, L.M., Nascimento, V.L., Araujo, F.F., Santos, M.N.S., Franca, C.F.M., Silva, T.P., Fugate, K.K., Finger, F.L., 2020. Selenium-ethylene interplay in postharvest life of cut flowers. *Frontiers in Plant Science*, 11: 584698.
- Dar R.A., Tahir I., 2018. Effect of ethylene antagonist silver thiosulphate on the flower longevity of *Clarkia pulchella* Pursh. *Journal of Horticultural Research*, 26(1): 5-12.
- Dar, R. A., Nisar, S., Tahir, I., 2021. Ethylene: a key player in ethylene sensitive flower senescence: a review. *Scientia Horticulturae*, 290, 110491.
- Darras, A.I., Akoumianaki-Ioannidou A., Pompodakis N.E., 2010. Evaluation and improvement of post-harvest performance of cut *Viburnum tinus* inflorescence. *Scientia Horticulturae*, 124(3): 376-380
- Darvish, M., Shirzad, H., Asghari, M., Noruzi, P., Alirezalu, A., Pateiro, M., ... Lorenzo, J. M., 2021. 24-Epibrasinolide modulates the vase life of lisianthus cut flowers by modulating acc oxidase enzyme activity and physiological responses. *Plants*, 10(5): 995.
- Devecchi, M., Trotta, F., Seglie, L., Kim, Y.J., Lava, C., Dolci, M., Scariot, V., 2009. Effects of anti-ethylene compounds included in nanosponges in improving the postharvest longevity of carnation (*Dianthus caryophyllus*) and buttercup (*Ranunculus asiaticus*) cut flowers. *Acta Horticulturae*, 847: 237-244
- Ebrahimzadeh, A., Jiménez, S., Da Silva, J.T., Satoh, S., Lao, M.T., 2008. Post-harvest physiology of cut carnation flowers. *Fresh Produce*, 2(2): 56-71.
- Elgimabi, M. E. N. E., Sliai, A.M., 2013. Effects of preservative solutions on vase life and postharvest qualities of taif rose cut flowers (*Rosa damascene* cv. Trigintipetala). *American-Eurasian Journal of Agriculture and Environmental Sciences*, 13(1): 72-80
- Etemadypoor, R., Etemadypoor, R., Ghorbani, N., 2023. Qualitative response and vase life of carnation (*Dianthus caryophyllus*) cut flowers treated with salicylic acid and benzyl adenine under cold storage conditions. *Flower and Ornamental Plants*, 7(2): 239-260.
- Farazmandi, M., Mirzakhani, A., Sajedi, N. A., Nasri, M., Gomariyan, M., 2020. Physiological characteristics and vase life responses of rose cut flowers (*Rosa hybrida* L. cv. 'Royal Baccara') to benzyl adenine and 1-methylcyclopropene. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 48(4): 2279-291.
- Farooq, S., Haq, A.U., Lone, M. L., Parveen, S., Altaf, F., Tahir, I., Alsahli, A. A., 2024. "From villain to hero": Harnessing the gaseous grace of nitric oxide for prolonged elegance in *Antirrhinum majus* L. cut

- spikes. Journal of King Saud University-Science, 36(6): 103217.
- Farooq, S., Lone, M.L., Altaf, F., Parveen, S., Tahir, I., 2021. Boric acid as a potential substitute for conventional ethylene antagonists in mitigating postharvest flower senescence of *Digitalis purpurea*. Ornamental Horticulture, 27: 516-525.
- Farooq, S., Lone, M.L., UI Haq, A., Parveen, S., Altaf, F., Tahir, I., 2022. Polyamines and ethylene action blocker (STS) effectively augment longevity and postharvest attributes in isolated flowers of *Digitalis purpurea* L. Journal of Applied Horticulture, 24(2); 212-218.
- Finger, F. L., Silva, T. P., Araujo, F. F., Barbosa, J.G., 2016. Postharvest quality of ornamental plants. Postharvest ripening physiology of crops. Innovations in postharvest technology series. CrC Press Taylor and Francis Group, 88.
- Gebremedhin H., Tesfaye B., Mohammed A., Tsegay D., 2013. Influence of preservative solutions on vase life and postharvest characteristics of rose (*Rosa hybrid*) cut flowers. International Journal of Biotechnology and Molecular Biology Research, 4(8): 111-118.
- Gun, S. (2020). Extending of vase life of *Narcissus tazetta* by AVG and antimicrobial agents. Journal of Postharvest Technology, 8: 27-34.
- Ha, S. T. T., In, B. C., 2022. Combined Nano Silver, α -Aminoisobutyric Acid, and 1-Methylcyclopropene Treatment Delays the Senescence of Cut Roses with Different Ethylene Sensitivities. Horticulturae, 8(6): 482.
- Ha, S. T. T., Kim, Y. T., Jeon, Y. H., Choi, H. W., In, B. C., 2021. Regulation of botrytis cinerea infection and gene expression in cut roses by using nano silver and salicylic acid. Plants, 10(6), 1241.
- Ha, S.T., Lim, J. H., In, B.C., 2019. Extension of the vase life of cut roses by both improving water relations and repressing ethylene responses. Horticultural Science and Technology, 37(1): 65-77.
- Ha, S.T.T., In, B.C., 2023. The retardation of floral senescence by simultaneous action of nano silver and AVG in cut flowers, which have distinct sensitivities to ethylene and water stress. Horticulture, Environment, and Biotechnology, 1-15.
- Ha, S.T.T., In, B.C., Choi, H.W., Jung, Y.O., Lim, J.H., 2017. Assessment of pretreatment solutions for improving the vase life and postharvest quality of cut roses (*Rosa hybrida* L. 'Jinny'). Flower Research Journal, 25(3): 101-109.
- Ha, S.T.T., Lim, J.H., In, B.C., 2020. Simultaneous inhibition of ethylene biosynthesis and binding using AVG and 1-MCP in two rose cultivars with different sensitivities to ethylene. Journal of plant growth regulation, 39: 553-563.
- Hajizadeh, S. H., Bayrami Aghdam, S., Fakhrghazi, H., Karakus, S., Kaya, O., 2024. Physico-Chemical Responses of *Alstroemeria* spp. cv. Rebecca to the presence of Salicylic Acid and Sucrose in vase solution during postharvest life. BMC Plant Biology, 24(1): 121.
- Haq, A. U., Lone, M. L., Farooq, S., Parveen, S., Altaf, F., Tahir, I., Allakhverdiev, S., 2021. Nitric oxide effectively orchestrates postharvest flower senescence: a case study of *Consolida ajacis*. Functional Plant Biology, 50(2): 97-107.
- Hashemabadi D., Liavali M.H., Kaviani B., Mousavi M., Keyghobadi S., Zahiri S., 2014. Effect of nano-silver and boric acid on extending the vase life of cut rose (*Rosa hybrida* L.). Journal of Environmental Biology, 35(5): 833.
- Hassan, F., 2016. The Role of 1-methylcyclopropene (1-MCP) in improving the postharvest quality of some cut rose cultivars. Journal of Ornamental Plants, 6(4): 261-270.
- Hassan, F., Ali, E., Mazrou, R., 2020. Involvement of ethylene synthetic inhibitors in regulating the senescence of cut carnations through membrane integrity maintenance. Journal of Horticultural Research, 28(1): 39-48.
- Hofmann, A., Minges, A., Groth, G., 2021. Interfering peptides targeting protein-protein interactions in the ethylene plant hormone signaling pathway as tools to delay plant senescence. Plant Chemical Genomics: Methods and Protocols, 71-85.
- Hongpakdee, P., Khammali, S., Kaewbua, K. and Banyai, K., 2022. Effects of chlorine releasing compound and ethylene inhibitors on vase life of 'Shimmer' cut gerbera. Acta Horticulture, 1336: 55-60
- Hoppen, C., Müller, L., Albrecht, A.C., Groth, G., 2019. The NOP-1 peptide derived from the central regulator of ethylene signaling EIN2 delays floral senescence in cut flowers. Scientific Reports, 9(1): 1287.
- Hussen S., Yassin H., 2013. Review on the impact of different vase solutions on the postharvest life of rose flower. International Journal of Agricultural Research and Review, 1(2): 13-17.
- Kasim, R., Kasim, M.U., 2015. The Methods to Prevent the Negative Effects of Ethylene on the Ethylene-Sensitive Cut Flowers. Conference: VI. International Scientific Agricultural Symposium, 1-9.
- Kato, M., Kanda, M., Ichimura, K., 2022. Effects of pulse treatments with sucrose, silver thiosulfate complex (STS) and calcium chloride on the vase life and soluble carbohydrate and aurone levels in cut snapdragon flowers. The Horticulture Journal, 91(1): 112-121.
- Kaur P., Mukherjee D., 2012. Delaying postharvest senescence of *Matricaria parthenium* L. flowers using ethanol, methanol and sucrose. Journal of Tropical Plant Physiology, 4: 1-16.
- Kaur P., Mukherjee D., 2013. Senescence regulation by alcohols in cut flowers of *Calendula officinalis* L. Acta Physiologiae Plantarum, 35(6): 1853-1861.
- Kazemi M., Ameri A., 2012. Effect of Ni, CO, SA and sucrose on extending the vase-life of lily cut flower. Iranica Journal of Energy and Environment, 3(2): 162-166.
- Kessenbrock, M., Klein, S. M., Müller, L., Hunsche, M., Noga, G., Groth, G., 2017. Novel protein-protein inhibitor based approach to control plant ethylene responses: synthetic peptides for ripening control. Frontiers in Plant

Science, 8: 1528.

- Khandan-Mirkohi, A., Pirgazi, R., Taheri, M. R., Ajdanian, L., Babaei, M., Jozay, M., Hesari, M. 2021. Effects of salicylic acid and humic material preharvest treatments on postharvest physiological properties of static cut flowers. *Scientia Horticulturae*, 283, 110009.
- Khella E.A., Abd-ElMoniem A.M., Mohamed A.M.B., 2018. Influence of some preservative solutions on vase life and postharvest qualities of limonium cut flowers. *Scientific Journal of Flowers and Ornamental Plants*, 5(1): 89-103.
- Khokhar M., Mukherjee D., 2013. Regulation of lipoxygenase and superoxide dismutase activities and longevity of chrysanthemum cut flowers by ethanol and methanol. *Indian Journal of Horticulture*, 70(1): 76-81.
- Khongwir N.K.L., Singh M.C., Singh K.P., Arora A., 2017. Postharvest quality of tuberose (*Polianthes tuberosa*) loose flower as affected by elicitor treatment. *Progressive Horticulture*, 49(1): 69-74
- Khunmuang, S., Kanlayanarat, S., Wongs-Aree, C., Meir, S., Philosoph-Hadas, S., Oren-Shamir, M., ... Buanong, M., 2019. Ethylene induces a rapid degradation of petal anthocyanins in cut Vanda 'Sansai Blue' orchid flowers. *Frontiers in Plant Science*, 10, 1004.
- Kiaseh D.Y., Yadegari M., 2016. The effect of ethanol and cycloheximide on the vase life of cut flowers alstroemeria (*Alstroemeria hybrida*). *Journal of Ornamental & Horticultural Plants*, 6(2): 73-82.
- Klein, S., Fiebig, A., Neuwald, D., Dluhosch, D., Müller, L., Groth, G., ... & Hunsche, M. (2019). Influence of the ethylene-related signal-inhibiting octapeptide NOP-1 on postharvest ripening and quality of 'Golden Delicious' apples. *Journal of the Science of Food and Agriculture*, 99(8): 3903-3909.
- Kondo, M., Nakajima, T., Shibuya, K., Ichimura, K., 2020. Comparison of petal senescence between cut and intact carnation flowers using potted plants. *Scientia Horticulturae*, 272: 109564.
- Kosugi, Y., Matsuoka, A., Higashi, A., Toyohara, N., Satoh, S., 2014. 2-Aminooxyisobutyric acid inhibits the in vitro activities of both 1-aminocyclopropane-1-carboxylate (ACC) synthase and ACC oxidase in ethylene biosynthetic pathway and prolongs vase life of cut carnation flowers. *Journal of Plant Biology*, 57: 218-224.
- Krause, M.R., Santos, M.N.D.S., Moreira, K.F., Tolentino, M.M., Mapeli, A.M., 2021. Extension of the vase life of *Lilium pumilum* cut flowers by pulsing solution containing sucrose, citric acid and silver thiosulfate. *Ornamental Horticulture*, 27(03): 344-350.
- Kshirsagar, S., Kumar, A., Singh, O., Gallani, R., Parmar, R., 2021. Effect of postharvest preservatives on vase life of cut rose (*Rosa hybrida* L.) cv. Top secret. *Journal of Pharmacognosy and Phytochemistry*, 10(1): 1056-1061.
- Kumar, R., Yadav, M.K., Shankar, B.A., Sharma, S., Rani, R., 2022. Effect of different chemicals to enhance vase life of tuberose (*Polianthes tuberosa* L.) cut flowers. *International Journal of Agricultural and Statistical Sciences*, 18(1): 995-1002.
- Kumari S., Raghupathi B., Sarika K., Deb P., 2018. Effect of different preservatives on vase-life of cut tuberose (*Polianthes tuberosa* L.) cv. Calculta Single. *International Journal of Current Microbiology and Applied Sciences*, 7(1): 1651-1657
- Kumari, M., Kumar, R., Nath Saha, T., Sindhu, S.S., 2016. Effect of polyamine and ethylene inhibitors on post harvest physiology of cut stems in chrysanthemum cv. Reagan White. *Indian Journal of Horticulture*, 73(4): 582
- Kwon, H.S., Leporini, C., Kim, S., Heo, S., 2024. Prolonged vase life by salicylic acid treatment and prediction of vase life using petal color senescence of cut lisianthus. *Postharvest Biology and Technology*, 209: 112726.
- Lezoul, N.E.H., Serrano, M., Ruiz-Aracil, M.C., Belkadi, M., Castillo, S., Valero, D., Guillén, F., 2022. Melatonin as a new postharvest treatment for increasing cut carnation (*Dianthus caryophyllus* L.) vase life. *Postharvest Biology and Technology*, 184: 111759.
- Li, X., Fang, P., Li, M., Xu, P., 2023. Identification of methyl 1-aminocyclopropanecarboxylate as a novel ethylene agonist: a structural analogy approach. *In Vitro Cellular & Developmental Biology-Plant*, 59(1): 61-73.
- Liao, W. B., Mei-Ling Zhang, Ji-Hua Yu., 2013. Role of nitric oxide in delaying senescence of cut rose flowers and its interaction with ethylene, *Scientia Horticulturae*, 155; 30-38.
- Mahmoudian, S.S., Etemadi, N., Amirikhah, R., Panahi, S., 2023. Sensitivity Consequences of Ethylene in Determining the Vase Life of *Eremurus spectabilis* and *E. persicus*. *Horticulturae*, 9(9): 978.
- Manimaran P., Ganga M., Kannan M., 2018. Manipulation of petal senescence in *Jasminum nitidum* flowers with packaging and pre-treatment during storage: Role of phenolics. *Journal of Pharmacognosy and Phytochemistry*, 7(2): 3478-3480.
- Mittal, I., Jhanji, S., Dhatt, K. K., 2021. Efficacy of sodium nitroprusside, a nitric oxide donor, on vase life and postharvest attributes of gladiolus spikes. *Acta Physiologiae Plantarum*, 43(7): 108.
- Moghaddam, N.N., Hashemabadi, H., Kaviani, B., Safari Motlagh, M.R., Khorrani Raad, M. (2021). Effect of sodium nitroprusside on the vase life of cut rose, lisianthus, and sunflower. *Journal of Ornamental Plants*, 11(3): 185-195
- Mohammadi M., Hashemabadi D., Kaviani B., 2012. Effect of cobalt chloride on vase life and post-harvest quality of cut tuberose (*Polianthes tuberosa* L.). *European Journal of Experimental Biology*, 2(6): 2130-2133.
- Mohammadi, K., Chavoshi, S., Asadi-Gharnehances H. A., Gomarian, M., Edrisi, B., 2024. Sodium nitroprusside enh , vase life of *Polianthes tuberosa* cut flowers by inducing defence enzymes. *The Journal of Horticultural Science and Biotechnology*, 1-10.

- Mohammadpour, R., Buanong, M., Jitareerat, P., Wongs-Aree, C., Uthairatanakij, A., 2025. Sodium nitroprusside an ethylene reduction inducer. An alternative that prolongs the shelf life of cut inflorescences of *Dendrobium* orchids. *Journal of the Selva Andina Research Society*, 16(1): 3-20.
- Moura, A.D., Mapeli, A.M., Finger, F.L., Barbosa, J.G., 2010. Vase life of *Epidendrum ibaguense* Kunth inflorescences treated with ethylene inhibitors. *Revista Brasileira de Horticultura Ornamental*, 16(2): 146-152.
- Naghiloo, S., Rabiei, V., Soleimani, A., Khalighi, A., Harkinezhad, T.M., 2019. Effect of aminooxyacetic acid (AOA) on ACS and ACO genes expression and the vase life of alstroemeria cut flower. *Genetika*, 51(3), 861-876.
- Naing, A. H., Soe, M.T., Kyu, S.Y., Kim, C.K., 2021. Nano-silver controls transcriptional regulation of ethylene-and senescence-associated genes during senescence in cut carnations. *Scientia Horticulturae*, 287, 110280.
- Naing, A.H., Win, N.M., Kyu, S.Y., Kang, I.K., Kim, C.K., 2022. Current progress in application of 1-Methylcyclopropene to improve postharvest quality of cut flowers. *Horticultural Plant Journal*, 8(6): 676-688
- Nasiri, A., Ahmadi, N., Movahed, G., 2020. Effects of 1MCP and ethylene on preservation of quality and vase life of *Alstroemeria* (cvs. Hercules and Mayfair) cut flowers. *Advances in Horticultural Science*, 34(1S): 89-96.
- Nazari F., Saba M.K., 2017. Combination effect of 1-methylcyclopropene (1-MCP) with ajowan essential oil and silver nanoparticles on postharvest life of gerbera (*Gerbera jamesonii*) cut flowers. *HortScience*, 52(11): 1550-1555.
- Nisar, S., Dar, R.A., & Tahir, I., 2021. Salicylic acid retards senescence and makes flowers last longer in *Nicotiana plumbaginifolia* (Viv). *Plant Physiology Reports*, 26: 128-136.
- Olsen, A., Lütken, H.V., Hegelund, J.N., Müller, R., 2015. Ethylene resistance in flowering ornamental plants - improvements and future perspectives. *Horticulture Research*, 2: 15038.
- Pérez-Arias, G.A., Alia-Tejacal, I., Colinas-León, M.T., Valdez-Aguilar, L.A., Pelayo-Zaldívar, C., 2019. Postharvest physiology and technology of the tuberose (*Polianthes tuberosa* L.): an ornamental flower native to Mexico. *Horticulture, Environment, and Biotechnology*, 60: 281-293.
- Piechocki R., Salachna P., 2019. Improvement of postharvest quality of cut amaranth (*Amaranthus tricolor* L.) foliage by ethanol. *World News of Natural Sciences*, 22: 151-158.
- Prabawati, S., Sjafrina, N., Sulistyaningrum, A., Rahayu, E., Widayanti, S. M., Waryat, ... Arif, A. B., 2023. Increasing the vase life of chrysanthemum cut flowers by using silver and zinc nanoparticles. *The Scientific World Journal*, 2023(1): 8871491
- Priyanka, M., Lakshminarayana, D., Gowthami, P., Sathish, G., 2024. Studies on the effect of ethylene inhibitors on extension of vase life of carnation cut flower (*Dianthus caryophyllus* L.) cv. dona under ambient conditions. *Plant Archives*, 24(1): 1181-1186.
- Pun, U.K., Yamada, T., Azuma, M., Tanase, K., Yoshioka, S., Shimizu-Yumoto, H., ... Ichimura, K., 2016. Effect of sucrose on sensitivity to ethylene and enzyme activities and gene expression involved in ethylene biosynthesis in cut carnations. *Postharvest biology and technology*, 121: 151-158.
- Qiu, H., Chen, Y., Fu, J., & Zhang, C., 2024. Expression of ethylene biosynthetic genes during flower senescence and in response to ethephon and silver nitrate treatments in *Osmanthus fragrans*. *Genes & Genomics*, 46(4): 399-408.
- Rabiza-Świder, J., Skutnik, E., Jędrzejuk, A., 2019. The effect of a sugar-containing preservative on senescence-related processes in cut clematis flowers. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 47(2): 432-440.
- Rani, P., Singh, N., 2014. Senescence and postharvest studies of cut flowers: a critical review. *Pertanika Journal of Tropical Agricultural Science*, 37(2): 159-201
- Sadeghi, S., Jabbarzadeh, Z., 2025. Vase Life and Postharvest Attributes of *Alstroemeria aurea* 'Orange Queen' as Influenced by the Application of Sodium Nitroprusside Before and After Harvest. *International Journal of Horticultural Science and Technology*, 12(4): 421-434.
- Sakr, W.R.A., 2016. Alternatives to Commercial Floral Preservatives for Improving Vase Life and Quality of Snapdragon Cut Flowers. *American-Eurasian Journal of Agriculture and Environmental Sciences*, 16(3): 584-593.
- Salaemae N., Satoh S., Imsabai W., Takeda S., Kaewsuksaeng S., 2018. The combination of EthylBloc Sachet and 2, 4-pyridinedicarboxylic acid reduces petal blackening and prolongs vase life of cut flowers of lotus (*Nelumbo nucifera* Gaerth) cvs. Sattabongkot and Saddhabutra. *Scientia Horticulturae*, 240: 133-138.
- Sales T.S., Paiva P.D.O., Siqueira H.H.D., Manfredini G.M., Lima L.C.D.O., 2018. Preservative solutions on quality and biochemical aspects of calla lily flowers. *Ciência e Agrotecnologia*, 42(2): 176-185.
- Sarhan, A.M., Heikal, A.A., Saadawy, F.M., El-Deen, T.M.N., Abd Elkareem, M.K., 2023. Effect of some chemical and natural preservative solutions on vase life, water relations and some chemical composition of *Dianthus caryophyllus* L. cut flowers. *Advances in Horticultural Science*, 37(3): 255-269.
- Sasikala S., Pradheeban L., Selvaskanthan S., 2015. Effect of different pulsing solutions on vase life of *Dieffenbachia maculata* cut foliage. *International Journal of Agricultural and Food Science*, 5(3): 109-114.
- Satoh, S., Makino, K., Shimada, K., Nomura, Y., 2020. Failure of 2-Pyridinecarboxylic Acid, an Inhibitor of 1-Aminocyclopropane-1-carboxylate Oxidase, as a Universal Flower Care Agent to Extend the Vase Life of Cut Carnation Flowers. *The Horticulture Journal*, 89(3): 300-305.
- Satoh, S., Nomura, Y., 2019. Promotion of flower opening of spray-type carnation cut flowers by 3-pyridinecarboxylic acid, a simple analog of pyridinedicarboxylic acids (PDCAs) including 2, 3-and 2, 4-PDCAs. *The Horticulture Journal*, 88(2): 293-298.

- Satoh, S., Nomura, Y., Morita, S., Sugiyama, S., 2016. Further characterization of the action of pyridinedicarboxylic acids: multifunctional flower care agents for cut flowers of spray-type carnation. *Journal of Applied Horticulture*, 18(1): 3-6.
- Satoh, S., Suetome, N., Namura, S., Kuwabara, H., 2008. Prolonged vase life of *Dianthus superbus* by 2-aminoisobutyric acid and cis-propenylboric acid. *Floriculture and Ornamental Biotechnology*, 2: 5-8.
- Scariot, V., Larcher, F., Caser, M., Costa, E., Beruto, M., Devecchi, M., 2009. Flower longevity in ten cultivars of cut *Ranunculus asiaticus* L. as affected by ethylene and ethylene inhibitors. *European Journal of Horticultural Science*, 74(3): 137-142.
- Scariot, V., Paradiso, R., Rogers, H., De Pascale, S., 2014. Ethylene control in cut flowers: Classical and innovative approaches. *Postharvest Biology and Technology*, 97: 83-92.
- Schaller, G. E., Binder, B.M., 2017. Inhibitors of ethylene biosynthesis and signaling. *Ethylene Signaling: Methods and Protocols*, 223-235.
- Sedaghatpour, S., Narouei, Z., Sajjadi, S. A., Piri, S., 2020. The effect of chemical treatments (silver thiosulfate and putrescine) on vase life and quality of cut *Chrysanthemum morifolium* (Ram.) flowers. *Cogent Biology*, 6(1): 1754320.
- Seglie, L., Martina, K., Devecchi, M., Roggero, C., Trotta, F., Scariot, V., 2011. The effects of 1-MCP in cyclodextrin-based nanosponges to improve the vase life of *Dianthus caryophyllus* cut flowers. *Postharvest Biology and Technology*, 59(2): 200-205.
- Serek, M., Woltering, E. J., Sisler, E. C., Frello, S., Sriskandarajah, S., 2006. Controlling ethylene responses in flowers at the receptor level. *Biotechnology advances*, 24(4): 368-381.
- Shibuya, K. (2018). Molecular aspects of flower senescence and strategies to improve flower longevity. *Breeding science*, 68(1): 99-108.
- Shimizu-Yumoto H., Ichimura K., 2010. Combination pulse treatment of 1-naphthaleneacetic acid and aminoethoxyvinylglycine greatly improves postharvest life in cut Eustoma flowers. *Postharvest Biology and Technology*, 56(1): 104-107.
- Shimizu-Yumoto, H., Ichimura, K., 2013. Postharvest characteristics of cut dahlia flowers with a focus on ethylene and effectiveness of 6-benzylaminopurine treatments in extending vase life. *Postharvest Biology and Technology*, 86: 479-486.
- Sisler, E. C., Serek, M., 1999. Compounds controlling the ethylene receptor. *Botanical Bulletin of Academia Sinica*, 40, 1-7.
- Sisler, E.C., Serek, M., 2003. Compounds interacting with the ethylene receptor in plants. *Plant Biology*, 5(5): 473-480.
- Sugawara, M., Okazaki, S., Nukui, N., Ezura, H., Mitsui, H., Minamisawa, K., 2006. Rhizobitoxine modulates plant-microbe interactions by ethylene inhibition. *Biotechnology Advances*, 24(4): 382-388.
- Sugiyama S., Satoh S., 2015. Pyridinedicarboxylic acids prolong the vase life of cut flowers of spray-type 'Light Pink Barbara' carnation by accelerating flower opening in addition to an already-known action of retarding senescence. *The Horticulture Journal*, 84(2): 172-177.
- Sui S., Luo J., Liu D., Ma J., Men W., Fan L., Bai Yu., Li M., 2015. Effects of hormone treatments on cut flower opening and senescence in wintersweet (*Chimonanthus praecox*). *HortScience*, 50(9): 1365-1369.
- Thwala M., Wahome K., Oseni O., Masariambi T., 2013. Effects of floral preservatives on the vase life of Orchid (*Epidendrum radicans* L.) cut flowers. *Journal of Horticultural Science and Ornamental Plants*, 5: 22-29.
- Tripathi, S. K., & Tuteja, N., 2007. Integrated signaling in flower senescence: an overview. *Plant Signal. Behavior*, 2: 437-445.
- Uddin A.J., Shamsuzzohaa M., Nusrata A., Taufiquea T., Mehrajb H., 2016. Vase life improvement of yellow gladiolus through different preservative solutions. *Journal of Bioscience and Agriculture Research*, 10(1): 837-842.
- Vijayalaxmi, M., Rao, A. M., Reddy, M. V., & Nirmala, A., 2022. Water relations and post harvest life of cut Gerbera as affected by ethylene inhibitors. *Environment and Ecology*, 40(4): 1965-1973.
- Wang R., Zheng X., Xu X., 2014. Evidence for physiological vascular occlusion in stems of cut gerbera cv. Hongyan. *Journal of Agricultural Science and Technology*, 16(2): 365-372.
- Wang, C., Fang, H., Gong, T., Zhang, J., Niu, L., Huang, D., ... Liao, W., 2020a. Hydrogen gas alleviates postharvest senescence of cut rose 'Movie star' by antagonizing ethylene. *Plant molecular biology*, 102, 271-285.
- Wang, M., Ni, C., Wang, R., Zhong, L., Cheng, Y., Bao, M., & Zhang, F., 2023. Variation in longevity of cut and in planta flowers of potted carnation varieties affected by their relationship with ethylene and water. *Ornamental Plant Research*, 3(1): 1-11.
- Wang, Y., Zhao, H., Liu, C., Cui, G., Qu, L., Bao, M., ... Wang, Y., 2020b. Integrating physiological and metabolites analysis to identify ethylene involvement in petal senescence in *Tulipa gesneriana*. *Plant Physiology and Biochemistry*, 149, 121-131.
- Wijayabandara S.M.K.H., Damunupola J.W., Krishnarajah S.A., Daundasekera W.A.M., Wijesundara D.S.A., 2018. Effect of different vase solutions on postharvest longevity of cut foliage *Ophiopogon japonicus*. *Ceylon Journal of Science*, 47(2): 195-199
- Williamson, V. G., Joyce, D. C., 2013. *Boronia heterophylla* vase life is influenced more by ethylene than by bacterial

numbers or vase solution pH. *Postharvest Biology and Technology*, 84, 28-35

- Wongjunta, M., Wongs-Aree, C., Salim, S., Meir, S., Philosoph-Hadas, S., Buanong, M., 2021. Involvement of ethylene in physiological processes determining the vase life of various hybrids of Mokara orchid cut flowers. *Agronomy*, 11(1): 160.
- Wu, L., Ma, N., Jia, Y., Zhang, Y., Feng, M., Jiang, C. Z., ... Gao, J., 2017. An ethylene-induced regulatory module delays flower senescence by regulating cytokinin content. *Plant Physiology*, 173(1): 853-862.
- Yagi M.I., Mohy Eldeen., Elgemaby N.E., 2014. Effect of bactericides and sucrose pulsing on longevity and vase life of rose cut flowers. *International Journal of Sciences: Basic and Applied Research*, 14(2): 117-129.
- Yi, W., Kaixuan, W., Siyuan, H., Shuang, Z, Guoan, S., 2021. Effects of Ethylene Metabolism and Energy Status on Vase Quality of Cut Itoh Peony 'Bartzella' Flowers. *Acta Horticulturae Sinica*, 48(6), 1135.
- Zeng, F., Xu, S., Geng, X., Hu, C., & Zheng, F., 2023. Sucrose+ 8-HQC improves the postharvest quality of lily and rose cut flowers by regulating ROS-scavenging systems and ethylene release. *Scientia Horticulturae*, 308; 111550.
- Zeng, Z., Jiang, H., Zhang, H., Jiang, Z., 2012. The synthesis of novel oxime ethers and their effects on the senescence of cut carnation flowers. *Research on Chemical Intermediates*, 38: 463-470.
- Zhou, Y., Liu, J., Xu, Y., Tan, J., Zhu, G., & Ye, Y., 2023. 6-Benzylaminopurine as a potential fresh-keeping agent for *Curcuma alismatifolia* cut flowers: Physiological and transcriptome analysis. *Postharvest Biology and Technology*, 205: 112540.