www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 2918-2925

www.thepharmajournal.com
Received: 15-05-2022
Accepted: 17-06-2022

Vishavjeet Jakhar
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

AK Baswal
College of Agriculture, Sumerpur (Pali), Agriculture University, Jodhpur, Rajasthan, India

Hitesh Kapoor
College of Agriculture, Sumerpur (Pali), Agriculture University, Jodhpur, Rajasthan, India

Vaibhav Patil
College of Agriculture, Sumerpur (Pali), Agriculture University, Jodhpur, Rajasthan, India

Corresponding Author:
Vishavjeet Jakhar
Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Pre-and/or Post-harvest application of methyl jasmonate, methyl salicylate and salicylic acid to maintain post-harvest quality of horticultural crops: A review

Vishavjeet Jakhar, AK Baswal, Hitesh Kapoor and Vaibhav Patil

Abstract
Methyl jasmonate (MeJA), methyl salicylate (MeSA) and salicylic acid (SA) are the signaling molecules enhance the levels of bioactive compounds and maintain the post-harvest life of numerous horticultural crops with their pre- and/or post-harvest applications. This review focuses on as how the pre- and/or post-harvest application of MeJA, MeSA and SA extend the post-harvest life and maintain the quality of numerous fruits, vegetables and ornamentals.

Keywords: Pre-harvest, post-harvest, MeSA, MeJA, SA, fruit quality

1. Introduction
Fruit ripening and senescence are the physiological process mediated by ethylene, a plant hormone which diffuses into and out of plant tissues from both endogenous and exogenous sources (Saltveit, 1999) [62]. The influence of ethylene on post-harvest quality of horticultural crops could be beneficial or deleterious depending on the type of fruit and its ripening stage (Baswal & Ramezanian, 2020) [12]. Various approaches such as application of edible coatings and packaging have been tried by various researches to retard the post-harvest ripening and senescence during storage (Baswal *et al*., 2020a, 2020b; Khorram *et al*., 2017) [9, 10]. Anti-senescence compounds such as MeJA, MeSA and SA have been registered by U.S. Food and Drug Administration (FDA) and considered as safe for human-health and environment (Ashghari & Hasanloo, 2015) [6].
MeJA is a volatile compound and was firstly discovered in the blooms of *Jasminum grandiflorum* and has since been found across the plant kingdom. Because of its flammability, MeJA plays an important role in plant cellular responses, plant defence mechanisms in response to insect-induced wounds, infections, and environmental challenges such drought, low temperature, and salinity plant-herbivore interactions, and plant-plant interactions (Cheong & Choi, 2003) [17]. Exogenous application of MeJA has been shown to prevent stress-induced lesions in intact and fresh-cut fruits and vegetables throughout their post-harvest period (Gonzalez-Aguilar *et al*., 2007) [24].
MeSA is a plant molecule derived from salicylic acid that plays an important role in plant growth and development, defence mechanisms, plant responses to various abiotic stressors and fruit ripening (Kumar, 2014) [38].
SA is an endogenous signal molecule that regulates stress responses and plant developmental processes including heat production, photosynthesis, stomatal conductance, transpiration, ion-uptake and transport, disease resistance, seed germination, sex polarization and crop yield (Klessig & Malamy, 1994) [35]. SA is a promising compound retards the post-harvest ripening and spoilage of stored fruits and vegetables (Asghari & Aghdam, 2010) [5].

2. Effect of pre-harvest application of MeJA on post-harvest quality of horticultural crops: Pre-harvest application of MeJA successfully investigated on several horticultural crops such as pomegranate, pineapple, raspberries, sweet cherry, plum and cauliflower (Table 1). Pre-harvest application of MeJA significantly maintained higher levels of bioactive compounds and delayed the softening of plums (Ozturk *et al*., 2014) [52]. Likewise, the pre-harvest application of MeJA significantly enhanced the storage life of Japanese plum (Karaman *et al*., 2013) [33].

In cauliflower, the pre-harvest application of MeJA considerably enhanced the quinone reductase activity (Ku *et al*., 2013).

3. Effect of postharvest application of MeJA on selected horticultural crops
The post-harvest application of MeJA has been successfully investigated in numerous horticultural crops such as apples, blueberries, citrus, loquat, strawberries, tomatoes and broccoli (Table 2).

3.1Fruits
3.1.1Apple
The post-harvest application of MeJA significantly induced the expression of genes involved in ethylene production and signaling system and enhanced the de-greening with minimal losses in fruit quality of stored apple (Fan *et al*., 1998; Lv *et al*., 2018).

3.1.2 Blueberry
The post-harvest application of MeJA significantly stimulated the production of H_2O_2, improved the antioxidant potential (Wang *et al*., 2009) [14], promoted disease resistance against mold growth and modulated phenyl propanoid pathway in blueberry fruit (Wang *et al*., 2020) [73].

3.1.3 Citrus
The post-harvest dipping of ‘Kinnow’ mandarin fruit in MeJA significantly extended the storage life, retarded the activities of fruit softening enzymes and maintained the fruit quality (Baswal *et al*., 2021; Baswal *et al*., 2020c) [11, 8]. The post-harvest dipping in MeJA successfully degreened the mandarin cv. ‘Arayana’ (Gomez *et al*., 2017) [20].

3.1.4 Strawberry
The post-harvest application of MeJA showed higher resistance to water stress (Wang, 1999) [76], accumulated higher levels of volatile compounds i.e. anthocyanins and total phenols and maintained overall fruit quality of strawberry fruit (Ayala-Zavala *et al*., 2005) [7].

3.1.5 Other fruits
It has been shown that the post-harvest application of MeJA significantly enhanced the levels of total phenols, total sugars and phenyl alanine (PAL) and lipoxygenase (LOX) activities in guava fruit (Gonzalez-Aguilar *et al*., 2004) [23]. MeJA significantly extended the storage life of papaya and avocado fruit (Gonzalez-Aguilar *et al*., 2003; Glowacz *et al*., 2017) [22]. Mango fruit treated with MeJA showed significantly reduced chilling injury (CI) symptoms during storage (Gonzalez-Aguilar *et al*., 2001) [21]. In peaches, the post-harvest application of MeJA significantly alleviated CI (Meng *et al*., 2009) [50]. Likewise, the post-harvest application of MeJA significantly enhanced the levels of betacyanin and antioxidant activity in dragon fruit (Mustafa *et al*., 2018) [51]. Fruits of loquat treated with MeJA significantly improved chilling tolerance, enhanced anti-oxidative enzymatic activity and unsaturated/saturated fatty acid ratio (Cao *et al*., 2009) [14].

3.2 Vegetables
3.2.1 Tomato
The post-harvest application of MeJA significantly elevated the levels of primary health-promoting components and alleviated CI in tomato fruit (Ding *et al*., 2001; Liu *et al*., 2018) [30].

3.2.2 Bell Pepper
The post-harvest application of MeJA alleviated CI and minimized the seed browning of bell paper (Wang *et al*., 2019; Seo *et al*., 2020) [77].

3.2.3 Broccoli
The post-harvest application of MeJA significantly enhanced the levels of health-promoting compounds such as phenolic content and antioxidant capacity of broccoli (Ku *et al*., 2013; Guan *et al*., 2019) [25].

3.2.4 Other Vegetables
In celery the post-harvest dipping of MeJA delayed spoilage and lowered the microbial growth (Buta & Moline, 1998) [13]. Likewise, combination of MeJA + MAP extended the storage life of garlic cloves garlic (Akan *et al*., 2019) [3].

3.3 Ornamentals
Pulsing with MeJA significantly showed higher resistance against mold and prevented the carotenoid degradation in cut roses (Meir *et al*., 1998; Glick *et al*., 2007) [49]. In gerbera, the post-harvest application of MeJA significantly improved the anthocyanin concentration, membrane stability index and catalase and peroxidase activities (Raviz, 2016) [59]. The post-harvest application of MeJA significantly delayed the senescence and lowered the wilt rate in cut freesia (Darras *et al*., 2005). In peony flower, the application of MeJA resulted in significantly reduced disease symptoms (Gast, 2001).

4. Effect of pre-harvest application of MeSA on post-harvest quality of horticultural crops
Pre-harvest application of MeSA significantly extended the storage life of crops such as apple, plum, cherries and vegetables like tomato (Table 3). In apples, the pre-harvest application of MeSA significantly enhanced the levels of phenolic compounds such as flavonols, chlorogenic acid, and cyaniding-3-glucoside (Gacnik *et al*., 2021) anti-oxidative compounds in plum (Serrano *et al*., 2018) [67] increased the fruit size with superior quality attributes in cherry (Gimenez *et al*., 2019).

5. Effect of post-harvest application of MeSA on post-harvest quality of selected horticultural crops
The post-harvest application of MeSA has been successfully investigated in several horticultural crops such as bananas, cherries, pears and tomatoes (Table 4).

5.1 Fruits
5.1.1 Banana
The post-harvest application of MeSA significantly increased the antioxidant defence mechanism, reduced the spoilage and delayed the post-harvest ripening in banana fruit (Cholmaitri *et al*., 2020; Chotikakham *et al*., 2020) [18].

5.1.2 Cherry
In cherries, the post-harvest application of MeSA significantly enhanced the antioxidant activity, maintained higher levels of bioactive compounds and maintained fruit quality (Castillo *et al*., 2015; Gimenez *et al*., 2016) [15].

5.1.3 Pear
Vapor application of MeSA significantly minimized the rate of chlorophyll degradation and delayed the fruit ripening (Zhang *et al*., 2020; 2019) [81].

5.1.4 Other fruits
In kiwifruits, the post-harvest application of MeSA significantly inhibited lignin synthesis (Suo *et al*. 2018) [71] lowered the electrolyte leakage, malondialdehyde (MDA), hydrogen peroxide (H_2O_2) concentrations and greater proline content in blood orange (Habibi *et al*., 2019) [26] and enhanced the resistance to low-temperature stress in mango fruit during storage (Han *et al*., 2006).

5.2 Vegetables
In tomato, the post-harvest application of MeSA significantly delayed the spoilage losses (Zhang *et al*., 2017) [40] and up-regulated the ethylene production (Ding & Wang, 2003) [22] and alleviated the CI in bell pepper (Rehman *et al*., 2021) [58].

6. Effect of pre-harvest application of SA on post-harvest life of horticultural crops
The pre-harvest application of SA has been successfully investigated in lemon, mango and grapes (Table 5). Pre-harvest application of SA significantly enhanced the physico-chemical attributes, reduced the incidence of mold colonization, improved phenolic compounds and biogenic amines and delayed the fruit ripening in grapes (Gomes *et al*., 2021; Garcia-Pastor *et al*., 2020; Lo'oy, 2017; Champa *et al*., 2014) [19, 66, 16] and extended the post-harvest life of lemon (Serna-Esacolano *et al*., 2021) mango (Reddy *et al*., 2016) [57] and gladiolus (Saeed *et al*., 2016) [60].

7. Effect of post-harvest application of SA on selected horticultural crops
Till date, the post-harvest application of SA has been successfully investigated in different horticultural crops such as apples, citrus, strawberries, peaches and ornamentals (Table 6).

7.1 Fruits
7.1.1 Apple
The post-harvest application of SA significantly minimized browning, induced disease resistance and extended the storage life of cold-stored apples (Zhao & Wang, 2015; Hadian-Deljou & Sarikhani 2013) [75, 27].

7.1.2 Citrus
The post-harvest application of SA significantly maintained higher levels of total phenols, total antioxidant activity, flavonoids, protein, and total free amino acids in cold-stored 'Kinnow' mandarin fruit (Baswal *et al*., 2021) [11] and maintained the quality attributes in cold-stored blood oranges cv. Moro (Aminifard *et al*., 2013) [4].

7.1.3 Strawberry
In strawberries, the post-harvest application of SA significantly delayed weight loss and spoilage and maintained higher contents of TA, ascorbic acid and anthocyanin (Kumar and Kaur, 2019 [39]; (Geransayeh *et al*., 2015).

7.1.4 Peach
In peaches, the post-harvest application of SA significantly maintained the higher levels of ascorbic acid, soluble solids concentration, total phenolics and total antioxidant activity (Tareen *et al*., 2012; Khademi and Ershadi, 2013) [72, 34].

7.1.5 Other Fruits
In pomegranate, the post-harvest application of SA significantly minimized CI, electrolyte leakage and loss in ascorbic acid content during storage (Sayyari *et al*., 2009) [64] delayed the post-harvest ripening in mango (Zheng *et al*., 2006) [14] and maintained the quality attributes in papaya (Hanif *et al*., 2020) [31].

7.3 Ornamentals
The post-harvest application of SA significantly delayed the senescence (Zamani *et al*., 2011) [78] and boosted total chlorophyll content in roses (Jahanbazi *et al*., 2014) [3] enhanced the levels of total phenols, proline content, lowered the electrolyte leakage and MDA concentration and improved the detoxification of ROS compounds in anthurium (Aghdam *et al*., 2016; Promyou *et al*., 2012) [2, 55], reduced lipid peroxidation (Mansouri, 2012) [45] and modulated anti-oxidative system in chrysanthemum (Rahmani *et al*., 2015) [56].

Table1. Effect of pre-harvest application of MeJA on post-harvest quality of selected horticultural crops

Crop	Applied concentration	Stage of application	Effect on post-harvest quality	Reference(s)
Apple (*Malus domestica* Borkh cv. 'Cripps Pink')	10 (mmol L^{-1})	169 days after full bloom	Enhanced the red flush and fruit quality for export	Shafiq *et al*. (2012) [68]
Avocado (*Persea americana* cv. 'Hass')	100 (μmol L^{-1})	14 days before harvest	Prevented the incidence of anthracnose	Glowacz *et al*. (2017)
Cherry (*Prunus avium* L. cvs. '0900 Ziraat', 'Regina' and 'Sweetheart')	2240 (mg L^{-1})	3 weeks before Harvest	Maintained the flesh stiffness of fruit	Saracoglu *et al*. (2017) [63]
Japanese plum (*Prunus salicina*Lindell cv. 'Fortune' and 'Friar')	2240 (mg L^{-1})	2 weeks before harvest	Increased the phenolic content of plum fruits to increase their firmness at harvest and boost their antioxidant capacity.	Ozturk *et al*. (2014) [52]
Cauliflower (*Brassica oleracea* var. botrytis cv. 'Candid Charm')	500 (μM)	4 days before Harvest	Health promoting compounds were improved without affecting the post-harvest quality	Ku *et al*. (2013)

Table 2: Effect of post-harvest application of MeJA on post-harvest quality of selected horticultural crop

Crop	Applied concentration of MeJA	Dipping time	Temperature (°C)	Effect on post-harvest quality	Reference(s)
Dragonfruit (*Hylocereus polyrhizus* L.)	0.01 and 0.1 (mM)	16 h	20	Increased antioxidant and betacyanin activity	Mustafa *et al.* (2018) [51]
Guava (*Psidium guajava* L.)	10^4 and 10^5 M	8h	20	Minimized the ion leakage and CI index	Gonzalez-Aguilar *et al.* (2003) [22]
Kiwifruit (*Actinidia deliciosa* cv. 'Jinkui')	0.1 (mmol L^{-1})	24h	20	Reduced post-harvest softening during storage	Pan *et al.* (2020) [53]
Loquat (*Eriobotrya japonica* cv. 'Fuyang')	10 (μmol L^{-1})	24h	20	Alleviated the incidence of CI	Cao *et al.* (2009) [14]
Bell pepper (*Capsicum annuum* L. cv. 'Champion')	10 (mmol L^{-1})	10 min	13	Minimized the risk of frostbite	Wang *et al.* (2019) [77]
Cut gerbera (*Gerbera jamesonii* cv.'Pink Elegance')	0.2 (μL L^{-1})	24 h	20±2	Increased the anthocyanin content and extended the vase life	Raviz (2016) [59]

Table 3: Effect of pre-harvest application of MeSA on post-harvest quality of selected horticultural crops

Crop	Applied MeSA concentration	Stage of application	Effect on post-harvest quality	Reference(s)
Plum (*Prunus salicina* Lindl. cv. 'Black Splendor')	0.5 (mM)	61, 91 and 94 days after full bloom	Plum quality features were significantly improved and maintained	Martínez-Esplaa *et al.* (2017) [11]
Cherry (*Prunus avium* L.cv.' Sweet Heart')	1.0 (mM)	At three different stages of fruit growth	Increased fruit size and maintained fruit quality	Gimenez *et al.* (2019)
Apple (*Malus domestica*cv. 'Topaz')	2 (mM)	At different intervals before harvest	Significantly increased the levels of polyphenols	Gacnik *et al.* (2021)
Plum (*Prunus salicina* Lindl. cv." Black Splendor", BS, and "Royal Rosa", RR)	0.5 (mM)	At 63, 77 and 98 days after full bloom	Fruit quality attributes such as antioxidant compounds were retained during storage	Martinez-Espla *et al.* (2017) [67]

Table 4: Effect of post-harvest application of MeSA on post-harvest quality of selected horticultural crops

Crop	Applied concentration	Time	Temperature	Effect on postharvest quality	Reference (s)
Banana (*Musa acuminate* cv. 'Sucrier')	2 (mM)	30 min	25 ± 1	Delayed the senescence	Chotikakham *et al.* (2020)
Sweet orange (*Citrus sinensis* L. Osbeck cv. 'Moro')	50 (μM) and 100 (μM)	18 h	20	Enhanced chilling tolerance during storage	Habibi *et al.* (2019) [26]
Cherry (*Prunus avium* L. cv. 'Early Lory')	0.1 (mM)	16 h	20	Maintained the fruit quality and increased the levels of bioactive compounds and antioxidant activity during storage.	Gimenez *et al.* (2016)
Mango (*Mangifera indica* L. cv. 'Zill')	0.1 (mM)	12 h	20	Enhanced resistance to low -temperature stress	Han *et al.* (2006)
Pear (*Pyrus bretschneideri* cv.'Zaosu')	0.05 (mmol $L^{-1)}$	24h	25 ± 2	Retarded ripening and senescence	Zhang *et al.* (2020) [81]
Sweet pepper (*Capsicum annuum*L. cv. 'Winner')	0.05 mmol L^{-1})	12 h	20 ± 1	Alleviated CI and maintained the fruit quality	Rehman *et al.* (2021) [58]
Cherry tomato (*Solanum lycopersicum* var. cerasiformecv. Messina)	0.05 (mM)	12h	20	Alleviated CI by stimulating arginine catabolism during storage	Zhang *et al.* (2011) [83]

Table 5: Effect of pre-harvest application of SA on post-harvest quality of selected horticultural crops

Crop	Applied concentration	Stage of application	Effect on postharvest quality	Reference (s)
Plum (*Prunus salicina* Lindl. cv. 'Royal Rosa' and 'President')	1 (mM)	63, 77 and 98 days after full bloom	Enhanced the levels of bioactive compounds such as total phenolics, total carotenoids and antioxidant activity during storage	Serrano *et al.* (2018) [67]
Grapes (*Vitis vinifera* L. cv. 'Superior Seedless')	0, 1, 2, and 4 (mM)	After fruit set, during berry variation and 14 days before harvests	Fruit ripening was delayed	Lo'ay (2017)
Cherry (*Prunus avium* L.cv. 'Sweet Heart' and 'Sweet Late')	0.5, 1.0 and 2.0 (mM)	98, 112 and 126 days after full bloom	Maintained overall fruit quality	Gimenez *et al.* (2014)
Mango (*Mangifera indica* cv. 'Amarpali')	75, 150 and 200 ppm	7 days before harvest	Delayed ripening and senescence and maintained fruit quality attributes	Reddy *et al.* (2016) [57]
Lilium (*Lilium longiflorum* L. cv. 'Tressor')	0, 50, 100 and 200 ppm	At bud stage initiation	Morphological traits were improved.	Hajizadeh and Aliloo (2013)

Table 6: Effect of post-harvest application of SA on post-harvest quality of selected horticultural crops

Crop	Applied concentration	Time	Temperature	Effect on post-harvest quality	Reference(s)
Mango (*Mangifera indica*L. cv. 'Matisu')	1 (mmol L^{-1})	2 min	20ºC	Enhanced disease resistance	Zeng *et al*. (2006)
Banana (*Musa acuminata*cv 'Hari chhal')	500 (µM) and 1000 (µM)	6h	20ºC	Delayed fruit ripening	Srivastava and Dwivedi (2000)
Pomegranates (*Punica granatum*cv. 'Malas Saveh')	2 (mM)	10 min	20ºC	Alleviated CI and electrolyte leakage was reduced in husk	Sayyari *et al*. (2011) [64]
Peach (*Prunus persica* cv. 'Elberta')	2 (mM)	5 min.	20ºC	Enhanced the storability of fruits	Khademi and Ershadi (2013) [34]
Plum (*Prunus salicina* Lindl.cv 'Qingnai')	1.5 (mM)	10 min	1ºC	Alleviated CI	Luo *et al*. (2011)
Tomato (*Lycopersicon esculentum* cv. 'Newton')	1 (mM) and 2 (mM)	5 min	1ºC	Enhanced chilling tolerance and minimized CI	Aghdam *et al*. (2012) [1]

8. Conclusion

Overall, it can be summarized that pre- and post-harvest application of MeJA, MeSA and SA are potential treatments to extend the postharvest life and to maintain the quality of miscellaneous horticultural crops. Furthermore, more researches are required to understand the diverse responses of MeJA, MeSA and SA on storage life and fruit quality of different horticultural crops.

9. References

1. Aghdam M, Asghari M, Khorsandi O, Mohayeji M. Alleviation of post-harvest chilling injury of tomato fruit by salicylic acid treatment. Journal of Food Science and Technology. 2012;51:2815-2820. https://doi.org/10.1007/s13197-012-0757-1
2. Aghdam MS, Jannatizadeh A, Sheikh-Assadi M, Malekzadeh P. Alleviation of post-harvest chilling injury in anthurium cut flowers by salicylic acid treatment. Scientia Horticultuare. 2016;202:70-76. https://doi.org/10.1016/j.scienta.2016.02.025
3. Akan S, Tuna GN, Yanmaz R. Methyl jasmonate and low-temperature can help for keeping some physic-chemical quality parameters in garlic (*Allium sativum* L.) cloves. Food Chemistry. 2019;270:546-553. https://doi.org/10.1016/j.foodchem.2018.07.085
4. Aminifard MH, Mohammadi S, Fatemi H. Inhibition of green mould in blood orange (*Citrus chinensis* var. Moro) with salicylic acid treatment. Archives of Phytopathology and Plant Protection. 2013;46:695-703. https://doi.org/10.1080/03235408.2012.749740
5. Asghari M, Aghdam M. Impact of salicylic acid on post-harvest physiology of horticultural crops. Trends in Food Science and Technology. 2010;21:502-509. https://doi.org/10.1016/j.tifs.2010.07.009
6. Asghari M, Hasanlooe AR. Methyl jasmonate effectively enhanced some defence enzymes activity and total antioxidant content in harvested Sabrosa strawberry fruit. Food Science and Nutrition. 2015;4:377-383. https://doi.org/10.1002/fsn3.300
7. Ayala-Zavala J, Wang S, Wang C, Gonzalez-Aguilar G. Methyl jasmonate in conjunction with ethanol treatment increases antioxidant capacity, volatile compounds and post-harvest life of strawberry fruit. European Food Research and Technology. 2005;221:731-738. https://doi.org/ 10.1007/s00217-005-0069-z
8. Baswal AK, Dhaliwal HS, Singh Z, Mahajan BVC, Gill KS. Post-harvest application of methyl jasmonate, 1-methylcyclopropene and salicylic acid extends the cold storage life and maintain the quality of 'Kinnow' Mandarin (*Citrus nobilis* L. X *C. deliciosa* L.) fruit. Postharvest Biology and Technology. 2020c;161:111064. https://doi.org/10.1016/j.postharvbio.2019.111064
9. Baswal AK, Dhaliwal HS, Singh Z, Mahajan BVC, Kalia A. Influence of carboxy methylcellulose, chitosan and beeswax coatings on cold storage life and quality of 'Kinnow' mandarin fruit. Scientia Horticultuare. 2020a;260:108887. https://doi.org/ 10.1016/j.scienta.2019.108887
10. Baswal AK, Dhaliwal HS, Singh Z, Mahajan BVC. Influence of types of modified atmospheric packaging (MAP) film on cold-storage and fruit quality of 'Kinnow' mandarin (*Citrus nobilis* Lour x *C. deliciosa Tenora*). International Journal of Fruit Science. 2020b;20:1552-1569. https://doi.org/10.1080/15538362.2020.1818163
11. Baswal A, Dhaliwal H, Singh Z, Mahajan BVC. Post-harvest application of methyl jasmonate, 1-methylcyclopropene and salicylic acid elevates health-promoting compounds in cold-stored 'Kinnow' mandarin (*Citrus nobilis* Lour x *C. deliciosa* Tenora) Fruit. International Journal of Fruit Science. 2021;21:147-157. https://doi.org/10.1080/15538362.2020.1860865
12. Baswal AK, Ramezanian A. 1-Methylcyclopropene potentials in maintaining the postharvest quality of fruits, vegetables, and ornamentals: A review. Journal of Food Processing and Preservation. 2020;45:1-10. https://doi.org/10.1111/jfpp.15129
13. Buta J, Moline H. Methyl jasmonate extends shelf life and reduces microbial contamination of fresh-cut celery and peppers. Journal of Agricultural and Food Chemistry. 1998;46:1253-1256. https://doi.org/10.1021/JF9707492
14. Cao S, Zheng Y, Wang K, Jin P, Rui H. Methyl jasmonate reduces chilling injury and enhances antioxidant enzyme activity in post-harvest loquat fruit. Food Chemistry. 2009;115:1458-1463. https://doi.org/10.1016/j.foodchem.2009.01.082
15. Castillo S, Valverde J, Guillen F, Zapata P, Diaz-Mula, H, Valero D. Methyl jasmonate and methyl salicylate affect differentially the post-harvest ripening process of 'Primulat' sweet cherry. Acta Horticulture. 2015;1079;541-544. https://doi.org/10.17660/ActaHortic.2015.1079.72
16. Champa W, Gill M, Mahajan B, Arora N. Pre-harvest salicylic acid treatments to improve quality and post-harvest life of table grapes (*Vitis vinifera* L.) cv. Flame Seedless. Journal of Food Science and Technology. 2014;52:3607-3616. https://doi.org/10.1007/s13197-014-1422-7
17. Cheong J, Choi Y. Methyl jasmonate as a vital substance

in plants. Trends in Genetics. 2003;19:409-413. https://doi.org/10.1016/S0168-9525(03)00138-0
18. Cholmaitri C, Uthairatanakij A Laohakunjit N, Jitareerat P, Mingvanish W. Controlled release of related enzymes in 'Hass' avocado fruit treated with methyl jasmonate and methyl salicylate. Food Chemistry. 2020;234:163-167. https://doi.org/10.1016/j.foodchem.2017.04.063
19. Gomes EP, Borges CV, Monteiro GC, Belin MAF, Minatel IO, Junior AP. Pre-harvest salicylic acid treatments improve phenolic compounds and biogenic amines in 'Niagara Rosada' table grape. Postharvest Biology and Technology. 2021;176:111505. https://doi.org/10.1016/j.postharvbio.2021.111505
20. Gomez CA, Herrera AO, Florez VJ, Balaguera-Lopez H. Methyl Jasmonate, a degreening alternative for mandarin (*Citrus reticulata* L.) var. Arrayana fruits. International Journal of Engineering Ressearch and Applications, 2017;7:22-29. https://doi.org/10.9790/9622-0707062229
21. Gonzalez-Aguilar GA, Buta JG, Wang CY. Methyl jasmonates reduces chilling injury symptoms and enhances color development of 'Keit' mangoes. Journal of Food Science and Agriculture 2001;81:1244-1249. https://doi.org/10.1002/jsfa.933
22. Gonzalez-Aguilar GA, Buta JG, Wang CY. Methyl jasmonate and modified atmosphere packaging (MAP) reduce decay and maintain post-harvest quality of papaya 'Sunrise'. Postharvest Biology and Technology. 2003;28:361-370. https://doi.org/10.1016/S0925-5214(02)00200-4
23. Gonzalez-Aguilar GA, Tiznado-Hernandez M, Zavaleta-Gatica R, Martıinez-Tellez M. Methyl jasmonate treatments reduce chilling injury and activate the defense response of guava fruits. Biochemistry and Biophysics Reports. 2004;313:694-701. https://doi.org/10.1016/j.bbrc.2003.11.165
24. Gonzalez-Aguilar GA, Villegas-Ochoa MA, Martinez-Tellez M, Gardea A, Ayala-Zavala JF. Improving antioxidant capacity of fresh-cut mangoes treated with UV-C. Journal of Food Science. 2007;72:197-202. https://doi.org/10.1111/j.1750-3841.2007.00295.x
25. Guan Y, Hu W, Jiang A, Xu Y, Sa R, Feng K. Effect of methyl jasmonate on phenolic accumulation in wounded broccoli. Molecules. 2019;24:3537. https://doi.org/10.3390/molecules24193537
26. Habibi F, Ramezanian A, Rahemi M, Eshghi S, Guillen F, Serrano M. Post-harvest treatments with γ -aminobutyric acid, methyl jasmonate, or methyl salicylate enhance chilling tolerance of blood orange fruit at prolonged cold storage. Journal of the Science Food and Agriculture. 2019;99:6408-6417. https://doi.org/10.1002/jsfa.9920
27. Hadian-Deljou M, Sarikhani H. Effect of salicylic acid on maintaining post-harvest quality of apple cv.‹ Golabe-Kohanz. Journal of Crop Improvement. 2013;14:71-82. https://doi.org/10.3923/ajpp.2011.113.119
28. Hajizadeh H, Aliloo A. The effectiveness of pre-harvest salicylic acid application on physiological traits in lilium (*Lilium longiflorum* L.) cut flower. International Journal of Environmental Science. 2013;1:344-350. https://doi.org/10.12983/ijsres-2013-p344-350
29. Han C, Zuo J, Wang Q, Dong H, Gao L. Salicylic acid alleviates post-harvest chilling injury of sponge gourd (*Luffa cylindrical* L.). Journal of Integrative Agriculture. 2017;16:735-741.
30. Han J, Tian S, Meng X, Ding Z. Response of physiologic metabolism and cell structures in mango fruit to exogenous methyl salicylate under low-temperature stress. Physiologia Plantarum. 2006;128:125-133. https://doi.org/10.1111/j.1399-3054.2006.00731.x
31. Hanif A, Ahmad S, Shahzad S, Liaquat M, Anwar R. Post-harvest application of salicylic acid reduced decay and enhanced storage life of papaya fruit during cold storage. Journal of Food Measurement and Characterization. 2020;14:3078-3088. https://doi.org/10.1007/s11694-020-00555-5
32. Jahanbazi T, Mortezaienejad F, Jafararpoor M. Impact of salicylic acid and jasmonic acid on keeping quality of rose (cv.' Angelina') flower. Journal of Novel Applied Science. 2014;3:1328-1335.
33. Karaman S, Ozturk B, Genc N, Celik SM. Effect of pre-harvest application of methyl jasmonate on fruit quality of plum (*Prunus Salicina* Lindell Cv. "Fortune") at harvest and during cold storage. Journal of Food Processing and Preservation. 2013;37:1049-1059. https://doi.org/10.1111/j.1745-4549.2012.00805.x
34. Khademi Z, Ershadi A. Post-harvest application of salicylic acid improves storability of peach (*Prunus persica* cv. Elberta) fruits. International Journal of Agriculture and Crop Sciences. 2013;5:651-655.
35. Klessig D, Malamy J. The salicylic acid signal in plants. Plant Molecular Biology. 1994;26:1439-1458. https://doi.org/10.1007/BF00016484
36. Ku K, Choi J, Kushad M, Jeffery E, Juvik J. Pre-harvest methyl jasmonate treatment enhances cauliflower chemoprotective attributes without a loss in post-harvest quality. Plant Foods for Human Nutrition. 2013;68:113-117. https://doi.org/10.1007/s11130-013-0356-y
37. Ku K, Jeffery E, Juvik J. Optimization of methyl jasmonate application to broccoli florets to enhance health-promoting phyto-chemical content. Journal of the Science of Food and Agriculture. 2014;94:2090-2096. https://doi.org/10.1002/jsfa.6529
38. Kumar D. Salicylic acid signaling in disease resistance. Plant Science. 2014;228:127-134. https://doi.org./10.1016/j.plantsci.2014.04.014
39. Kumar S, Kaur G. Effect of pre and post-harvest applications of salicylic acid on quality attributes and storage behaviour of strawberry cv. Chandler. Journal of Pharmacogonosy and Phytochemistry. 2019;8:516-522.
40. Li H, Suo J, Han Y, Liang C, Jin M, Zhang Z. The effect of 1-methylcyclopropene, methyl jasmonate and methyl salicylate on lignin accumulation and gene expression in post-harvest 'Xuxiang' kiwifruit during cold storage. Postharvest Biology and Technology. 2017;124:107-108. http://doi.org/10.1016/j.postharvbio.2016.10.003
41. Liu H, Meng F, Miao H, Chen S, Yin T, Hu S. Effects of post-harvest methyl jasmonate treatment on main health-promoting components and volatile organic compounds in cherry tomato fruits. Food Chemistry. 2018;263:194-200. https://doi.org/10.1016/j.foodchem.2018.04.124
42. Lo'ay AA. Pre-harvest salicylic acid and delay ripening of 'superior seedless' grapes. Egyptian Journal of Basic and Applied Science. 2017;4:227-230. https://doi.org/10.1016/j.ejbas.2017.04.006
43. Luo Z, Chen C, Xie J. Effect of salicylic acid treatment on alleviating post-harvest chilling injury of 'Qingnai'

plum fruit. Postharvest Biology and Technology. 2011;62:115-120. https://doi.org/10.1016/j.postharvbio.2011.05.012
44. Lv J, Zhang M, Zhang J, Ge Y, Li C, Meng K. Effects of methyl jasmonate on expression of genes involved in ethylene biosynthesis and signaling pathway during post-harvest ripening of apple fruit. Scientia Horticulturae, 2018;229:157-166. https://doi.org/10.1016/j.scienta.2017.11.007
45. Mansouri H. Salicylic acid and sodium nitroprusside improve post-harvest life of chrysanthemums. Scientia Horticulturae. 2012;145:29-33. https://doi.org/10.1016/j.scienta.2012.07.016
46. Martinez-Espla A, Serrano M, Valero D, Martinez-Romero D, Castillo S, Zapata P. Enhancement of antioxidant systems and storability of two plum cultivars by pre-harvest treatments with salicylates. International Journal of Molecular Sciences. 2017;18:1-14. https://doi.org/10.3390/ijms18091911
47. Martinez-Espla A, Zapata P, Valero D, Martinez-Romero D, Diaz-Mula H, Serrano M. Pre-harvest treatments with salicylates enhance nutrient and antioxidant compounds in plum at harvest and after storage. Journal of the Science of Food and Agriculture. 2017;98:2742-2750. https://doi.org/10.1002/jsfa.8770
48. Martinez-Romero D, Castillo S, Guillen F, Paladine D, Zapata P, Valero D. Rosehip oil coating delays post-harvest ripening and maintains quality of European and Japanese plum cultivars. Postharvest Biology and Technology. 2019;155:29-36. https://doi.org/10.1016/j.postharvbio.2019.05.005
49. Meir S, Droby S, Davidson H, Alsevia S, Cohen L, Horev B. Suppression of Botrytis rot in cut rose flowers by post-harvest application of methyl jasmonate. Postharvest Biology Technology. 1998;13:235-243. https://doi.org/10.1016/S0925-5214(98)00017-9
50. Meng X, Han J, Wang Q, Tian S. Changes in physiology and quality of peach fruits treated by methyl jasmonate under low-temperature stress. Food Chemistry. 2009;114:1028-1035. https://doi.org/10.1016/j.foodchem.2008.09.109
51. Mustafa M, Ali A, Seymour G, Tucker G. Treatment of dragonfruit (*Hylocereus polyrhizus* L.) with salicylic acid and methyl jasmonate improves post-harvest physico-chemical properties and antioxidant activity during cold storage. Scientia Horticulturae. 2018;231:89-96. https://doi.org/10.1016/j.scienta.2017.09.041
52. Ozturk B, Yıldız K, Kucuker E. Effect of pre-harvest methyl jasmonate treatments on ethyleneproduction, water-soluble phenolic compounds and fruit quality of Japanese plums. Journal of the Science of Food and Agriculture. 2014;95:583-591. https://doi.org/10.1002/jsfa.6787
53. Pan L, Zhao X, Chen M, Fu Y, Xiang M, Chen J. Effect of exogenous methyl jasmonate treatment on disease resistance of postharvest kiwifruit. Food Chemistry, 2020;305:125483. https://doi.org/10.1016/j.foodchem.2019.125483
54. Physiological and biochemical responses of horticultural products to methyl jasmonate. Stewart Postharvest Review. 2006;2:1-9.
55. Promyou S, Ketsa S, Doorn WGV. Salicylic acid alleviates chilling injury in anthurium (*Anthurium andraeanum* L.) flowers. Postharvest Biology and Technology. 2012;64:104-110. https://doi.org.10.1016/j.postharvbio.2011.10.002
56. Rahmani I, Ahmadi N, Ghanati F, Sadeghi M. Effects of salicylic acid applied pre- or post-transport on post-harvest characteristics and antioxidant enzyme activity of gladiolus cut flower spikes. New Zealand Journal of Crop and Horticultural Science. 2015;43:294-305 https://doi.org/10.1080/01140671.2015.1096799
57. Reddy S, Sharma R, Srivastav M, Kaur C. Effect of pre-harvest application of salicylic acid on post-harvest behaviour of 'Amrapali' mango fruits during storage. Indian Journal of Horticulture. 2016;73:405-409. https://doi.org/10.5958/0974-0112.2016.00086.4
58. Rehman R, Malik A, Khan A, Hasan M, Anwar R, Ali S. Combined application of hot water treatment and methyl salicylate mitigates chilling injury in sweet pepper (*Capsicum annuum* L.) fruits. Scientia Horticulturae, 2021;283:110113. https://doi.org/10.1016/j.scienta.2021. 110113
59. Raviz. Enhancement of postharvest quality and antioxidant enzymes' activity of gerbera cut flowers through methyl jasmonate fumigation. Acta Horticulture, 2016;1131:17-20.
60. Saeed T, Hassan I, Abbasi N, Jilani G. Antioxidative activities and qualitative changes in gladiolus cut flowers in response to salicylic acid application. Scientia Horticulturae. 2016;210:236-241. https://doi.org/10.1016/j.scienta.2016.07.034
61. Salimi F, Shekari F, Hamzei J. Methyl jasmonate improves salinity resistance in German chamomile (*Matricaria chamomilla* L.) by increasing activity of antioxidant enzymes. Acta Physiologiae Plantarum. 2015;38:1-14. https://doi.org/10.1007/s11738-015-2023-4
62. Saltveit ME. Effect of ethylene on quality of fresh fruits and vegetables. Postharvest Biology and Technology, 1999;15:279-292. https://doi.org/10.1016/S0925-5214(98)00091-X
63. Saracoglu O, Ozturk B, Yildiz K, Kucuker E. Pre-harvest methyl jasmonate treatments delayed ripening and improved quality of sweet cherry fruits. Scientia Horticulturae. 2017;226:19-23. https://doi.org/10.1016/j.scienta.2017.08.024
64. Sayyari M, Babalar M, Kalantari S, Martínez-Romero D, Guillen F, Serrano M. Vapour treatments with methyl salicylate or methyl jasmonate alleviated chilling injury and enhanced antioxidant potential during post-harvest storage of pomegranates. Food Chemistry. 2011;124:964-970. https://doi.org/10.1016/j.foodchem.2010.07.036
65. Seo J, Yi G, Lee J, Choi J, Lee E. Seed browning in pepper (*Capsicum annuum* L.) fruit during cold storage is inhibited by methyl jasmonate or induced by methyl salicylate. Postharvest Biology and Technology. 2020;166:111210. https://doi.org/10.1016/j.postharvbio.2020.111210
66. Serna-Escolano V, Martínez-Romero D, Gimenez M, Serrano M, Garcia-Martinez S, Valero D. Enhancing antioxidant systems by pre-harvest treatments with methyl jasmonate and salicylic acid leads to maintain lemon quality during cold storage. Food Chemistry. 2021;338:128044. https://doi.org/10.1016/j.foodchem.20 20.128044

67. Serrano M, Gimenez M, Martinez-Espla A, Valverde J, Martinez-Romero D, Castillo S. Effects of pre-harvest salicylate treatments on quality and antioxidant compounds of plums. Acta Horticulture. 2018;1194:121-126. https://doi.org/10.17660/ActaHortic.2018.1194.19
68. Shafiq M, Singh Z, Khan A. Time of methyl jasmonate application influences the development of 'Cripps Pink' apple fruit color. Journal of the Science of Food and Agriculture. 2012;93:611-618. https://doi.org/10.1002/jsfa.5851
69. Soleimani AM, Jannatizadeh A, Sheikh-Assadi M, Malekzadeh P. Alleviation of post-harvest chilling injury in anthurium cut flowers by salicylic acid treatment. Scientia Horticulturae. 2016;202:70-76. https://doi.org/10.1016/j.scienta.2016.02.025
70. Srivastava M, Dwivedi U. Delayed ripening of banana fruit by salicylic acid. Plant Science. 2000;158:87-96. https://doi.org/10.1016/s0168-9452(00)00304-6
71. Suo J, Li H, Ban Q, Han Y, Meng K, Jin M. Characteristics of chilling injury-induced lignification in kiwifruit with different sensitivities to low temperatures. Postharvest Biology and Technology. 2018;135:8-18. https://doi.org/10.1016/j.postharvbio.2017.08.020
72. Tareen, M. J., Abbasi, N. A., & Hafiz, I. A. (2012). Effect of salicylic acid treatments on storage life of peach fruits cv.'Flordaking'. Pakistan Journal of Botany, 44, 119-124.
73. Wang H, Kou X, Wu C, Fan G, Li T. Methyl jasmonate induces the resistance of postharvest blueberry to grey mold caused by *Botrytis cinerea*. Journal of the Science Food and Agriculture. 2020;100:4272-4281. https://doi.org/10.1002/jsfa.10469
74. Wang K, Jin P, Cao S, Shang H, Yang Z, Zheng Y. Methyl jasmonate reduces decay and enhances antioxidant capacity in Chinese bayberries. Journal of Agricultural and Food Chemistry. 2009;57:5809-5815. https://doi.org/10.1021/jf900914a
75. Wang L, Baldwin E, Plotto A, Luo W, Raithore S, Yu Z. Effect of methyl salicylate and methyl jasmonate pre-treatment on the volatile profile in tomato fruit subjected to chilling temperature. Postharvest Biology and Technology. 2015;108:28-38. https://doi.org/10.1016/j.postharvbio.2015.05.005
76. Wang S. Methyl Jasmonate Reduces Water Stress in Strawberry. Journal of Plant Growth Regulation. 1999;18:127-134. https://doi.org/10.1007/pl00007060
77. Wang Y, Gao L, Wang Q, Zuo J. Low-temperature conditioning combined with methyl jasmonate can reduce chilling injury in bell pepper. Scientia Horticulturae, 2019;243:434-439. https://doi.org/10.1016/j.scienta.2018.08.031
78. Zamani S, Kazemi M, Aran M. Post-harvest life of cut rose flowers as affected by salicylic acid and glutamin. World Applied Sciences Journal. 2011;12:1621-1624.
79. Zeng K, Cao J, Jiang W. Enhancing disease resistance in harvested mango (*Mangifera indica* L. cv. 'Matisu') fruit by salicylic acid. Journal of the Science of Food and Agriculture. 2006;86:694-698. https://doi.org/10.1002/jsfa.2397
80. Zhang H, Wang R, Wang T, Fang C, Wang J. Methyl salicylate delays peel yellowing of 'Zaosu' pear (*Pyrus bretschneideri* L.) during storage by regulating chlorophyll metabolism and maintaining chloroplast ultrastructure. Journal of the Science of Food and Agriculture. 2019;99:4816-4824. https://doi.org/10.1002/jsfa.9737
81. Zhang H, Zhao L, Fan C, Wang P, Cui M, Liu L. Impact of methyl salicylate on storage quality, ethylene action, and protein profiling of 'Zaosu' pear (*Pyrus bretschneideri* L.). Scientia Horticulturae. 2020;264:109196. https://doi.org/10.1016/j.scienta.2020.109196
82. Zhang X, Min D, Li F, Ji N, Meng D, Li L. Synergistic effects of L-arginine and methyl salicylate on alleviating post-harvest disease caused by *Botrysis cinerea* in tomato fruit. Journal of Agricultural and Food Chemistry. 2017;65:4890-4896. https://doi.org/10.1021/acs.jafc.7b00395
83. Zhang X, Shen L, Li F, Meng D, Sheng J. Methyl salicylate-induced arginine catabolism is associated with up-regulation of polyamine and nitric oxide levels and improves chilling tolerance in cherry tomato fruit. Journal of Agricultural and Food Chemistry. 2011;59:9351-9357. https://doi.org/10.1021/jf201812r
84. Zhao Y, Wang C. Effect of calcium chloride in combination with salicylic acid on post-harvest freshness of apples. Food Science and Biotechnology. 2015;24:1139-1146. https://doi.org/10.1007/s10068-015-0145-5