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Effect of post-harvest application of salicylic acid and methyl salicylate on different fruit crops

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Abstract
Methyl salicylate and Salicylic Acid, as a chemical component and nonvolatile chemical signal essential for the establishment of acquired resistance. Salicylic acid is produced naturally in plants and is involved in a variety of processes. SA and methyl salicylate (Mesa) treatments boost postharvest chilling injury resistance in horticultural crops. In this review paper discussed on various managements done after harvesting of different horticultural crops by application of methyl salicylate and salicylic acid. And additional goal of this review is to provide growers with more information about the various factors that influence on the application of this chemicals.

Keywords: Methyl salicylate, salicylic acid, postharvest application, storage, postharvest loss, shelf life, fruit crops

Introduction
Methyl salicylate (MeSA) is a chemical constituent of wintergreen. It is removed with steam from water-soaked and heated winter green leaves. Consequently, MeSA is commonly known as wintergreen oil. In 1843, the French chemist August Andre Thomas extracted the chemical from the plant Gaultheria procumbens and separated it. It was discovered to be a combination of salicylic acid and methanol. Salicylic acid is a chemical signal that is indispensable for the establishment of acquired resistance and the local and systemic production of antimicrobial pathogenesis-related protein. Methyl salicylate is a salicylic acid derivative. The treatment of seeds with MeSA is favourable for the seed industry, as it results in increased yield and growth. MeSA has been recommended by academics as a method to enhance fruit's chill resistance (Ding *et al.*, 2001; Fung *et al.*, 2004) and assistance in the ripening process (Ding and Wang 2003). It can be synthesized and is used as a fragrance, flavouring agent, and in foods and beverages. It yields a colorless to yellow or red liquid with a distinct aroma and taste of wintergreen (USCG-us coast guard, 1999). MeSA is a common herbivore-induced plant volatile that, when applied to crops, has the potential to increase natural enemy abundance and pest control. As an antioxidant capacity inducer, exogenous salicylic acid regulates physiological processes such as germination, stomatal opening, photosynthesis, and cell growth. MeSA initiates plant resistance in response to stress induced by biological factors, especially during pathogen invasion. MeSA is a toxic substance with a high level of toxicity. As little as 101 mg of MeSA is sufficient to kill an adult human. Even 4ml has proven to be fatal for children.

MeSA has the potential to create and automate plant-to-plant communication by transmitting signals through the air to the same or neighboring plant parts so that they can notify the other plants. V Shulaev *et al.*, 1997 MeSA in liquid form can be utilized as a vapour or a dipping technique. (Glowacz and Rees, 2016; Gimenez M.J. *et al.*, 2016 [12]; Sayyari *et al.*, 2011). SA shows good impact on horticultural crops by maintaining weight loss and other parameters (Asghari *et al.*, 2010) [24] Salicylic acid is naturally produced by plants and is involved in numerous processes. By synthesis or release from inactive conjugates, pathogen attack causes an increase in the concentration of cellular SA. The induction of numerous defense responses in tomato coincides with the rise in SA. It has been demonstrated that pre-treatment with SA increases the activity of alternative oxidase, which is responsible for greater heat tolerance and freezing tolerance in certain plants. According to new research, MeSA may act as an airborne signal to activate disease resistance and the production of defense-related genes in surrounding plants and healthy tissues of diseased plants. And Methyl salicylate mitigated the reduction of volatiles in tomatoes caused by chilling. (Libin Wang *et al.*, 2015) [19].

Salicylic acid, also known as ortho-hydroxy benzoic acid, is prevalent in plants and has a rich history dating back to 1878, when it was the most widely used drug in the world, manufactured in Germany (Raskin *et al.*, 1990) [30]. The term "salicylic acid" was coined by Rafale Piria in 1938, derived from the Latin word "Salix," which means "willow tree." SA has been identified in 36 diversely grouped plants (Raskin *et al.*, 1990) [30]. Due to its many regulatory functions in plant metabolism, salicylic acid is considered a potent plant hormone (Popova *et al.*, 1997) [26]. (Raskin, 1992a) Salicylic acid (SA), a phenolic molecule widely distributed in plants and now cinnamomic as a hormone component that regulates an immense wide range of physiological processes, is widely distributed in plants. Exogenous SA has been shown to delay ripening and softness of banana (Srivastava and Dwivedi, 2000) [34] and kiwifruit (Zhang *et al.*, 2003) [36] fruit, reduce lipid peroxidation of navel orange (Huang *et al.*, 2008), and enhance host resistance to postharvest diseases of sweet cherry (Huang *et al.*, 2008) [36]. (Qin *et al.*, 2003). Recent publications on the effects of SA on chilling injury reveal that SA and methyl salicylate (MeSA) treatments increase resistance to postharvest chilling injury in horticultural crops. Tomato (Ding *et al.*, 2001), loquat (Cai *et al.*, 2006), mango (Ding *et al.*, 2007), peach (Wang *et al.*, 2006; Cao *et al.*, 2010), pomegranate (Sayyari *et al.*, 2009), and pineapple (Sayyari *et al.*, 2009) have all been studied for their antioxidant properties (Sayyari *et al.*, 2009). (Lu *et al.*, 2010) Ber. As a result, SA therapy can control freezing damage in commercially harvested fruit. To our knowledge, however, the effect of SA therapy on physiological and biochemical alterations associated with chilling injury and post-storage quality in plum fruit remains unknown. And it has been discovered that SA induces a broad spectrum of metabolic and physiological responses in plants, thereby influencing their growth and development. As a natural and safe phenolic compound, SA has great potential for preventing post-harvest crop losses in horticulture. The post-harvest application of SA maintained well in strawberry and lowered the fungal contamination (Asghari 2006) [4] and post-harvest application of SA effectively controlled diseases and disorders in cold storage of pear fruit. Postharvest treatment of salicylic acid effectively controls pear fruit diseases and disorders during cold storage (Asghari *et al.*, 2007) [7]. Our study's objectives were to characterize the physiological and biochemical responses of 'Qingnai' plums to SA treatment and to evaluate its potential as a postharvest strategy for preventing chilling injury following cold storage. The effects of SA treatment on chilling injury, disease incidence, electrolyte leakage, malondialdehyde (MDA) content, respiration rate and ethylene production, polyphenol oxidase (PPO) and peroxidase (POD) activities, and polyamine contents were studied during postharvest storage of the fruit. As a natural and safe phenolic compound, SA has great potential for preventing post-harvest crop losses in horticulture. In all SA- and SNP-treated stems, electrolyte loss was reduced. (Hakimesh *et al.*, 2012). Postharvest quality of orange fruit is maintained by the post-harvest application of salicylic acid (Amiri *et al.*, 2021) [1]. The application of SA as post-harvest treatment maintained well in less spoilage and good sugar levels in guava (Asghari *et al.*, 2013) [3].

Role of mesa in banana

'Sucrier', A banana variety that causes great challenges for growers and dealers since its best eating quality time corresponds with the crop's problems, such as physiological dysfunction and senescent peel spots, during its later ripening stage. To address these difficulties, the bananas are soaked in a 2mM MeSA solution for about 30 minutes, dried, and then stored at a temperature of 25 °C for 6 days. This treatment aids in detecting reactive oxygen species production, ascorbate glutathione (ASA-GSH) cycle activity, peel spots, and oxidative membrane damage. Peel spotting appears to be associated with an increase in ROS production as well as oxidative membrane damage. However, as the peel spots increased, the activities and contents of the ASA-GSH cycle reduced. For a storage duration of 5 to 6 days, MeSA treatment boosted both enzymatic and non-enzymatic activity of the ASA-GSH cycle. When ROS levels are reduced, the ASA-GSH cycle activity increases significantly. This shows that increasing the activity of the ASA-GSH cycle with MeSA during storage can reduce spotting and activate an antioxidant defense system to combat various diseases. S. Chotijakham and colleagues (Chotijakham *et al.*, 2020). And delayed mitochondrial cytochrome c release and capsize 3 like activity (Aussara Panya *et al.*, 2022) [33].

Role of mesa in pomegranate

Pomegranates were treated with methyl Jasmonate (MeJa) or by methyl salicylate (MeSa) at two concentrations (0.01 and 0.1mM) after harvest and stored for 84 days at room temperature. Chilling injury (CI) signs included pitting and browning, with the severity increasing as storage duration increased, as well as softening and electrolyte leakage in control fruits (EL). MeJa or MeSa therapies significantly reduced CI symptoms, with no significant variations between treatments or doses given. Furthermore, when compared to controls, both treatments considerably enhanced total phenolics and anthocyanins. Total antioxidant activity in both hydrophilic (H-TAA) and lipophilic (L-TAA) arils decreased in control arils but increased in MeJa and MeSa treated 5fruit. The hydrophilic index rose, whereas the lipophilic index remained unchanged. Both MeJa and MeSa may have postharvest applications in lowering CI, maintaining quality, and promoting the health benefits of pomegranate fruit intake by increasing antioxidant capacity, according to the findings. Sayyari *et al.*, (2010) [31].

Role of mesa in kiwi

In kiwi fruit, MeSA with the combination of MeJA can limit lignin accumulation to some extent; however, 1-MCP may exacerbate lignin deposition, particularly in core tissue, mostly by up regulating AcPOD1, a lignin production enzyme. (Aghdam *et al.*, 2010) [24] Lignin has been found in the pulp and core of kiwifruit, and it has been shown to develop progressively from the stem to the calyx. Fruit firmness can be maintained at a higher level during cold storage by using 1-methylcyclopropene (1-MCP), but this comes at the cost of dramatically increased activities of phenylalanine ammonia-lyase, cinnamyl-alcohol dehydrogenase, and peroxidase, as well as lignification, which happens later in the storage period. Later phases of lignification were considerably suppressed by MeJA and MeSA. Deceases the lignin content by the application (Hua Li *et al.*, 2017) [15].

Role of mesa in sweet cherry

When held at 2 °C for around 20 days, post-harvest treatment of mesa in sweet cherry (early Lori) has demonstrated to be effective in weight loss, decreasing rate of respiration, texture softening, lowering acidity loss, and increasing the ripening index. Even at the end of the 20-day storage window, the Mesa treatment helped to preserve larger amounts of phenolics, antioxidant activity, hydrophilic extracts, and anthocyanins. Mesa increases the content of physiologically active chemicals and antioxidant activity in sweet cherries when administered as a post-harvest 6vapor during storage. Mesa treatment in the form of vapor has been classified as a cost-effective way to delay ripening and maintain quality features in sweet cherries. (M.J. Gimenez *et al.*, 2016) [12].

Role of mesa in mango

The pericarp wax surface had many cracks in MeSA-treated fruit, while the excerpt cells were separated normally. In MeSA-treated fruit, pectin compounds, aliphatic, and phenolics were found in lower concentrations in the excerpt cell wall. Furthermore, fruit that had been treated with MeSA had more esterified compounds and fewer carboxylate and carboxyl chemicals. The importance of MeSA in improving fruit tolerance to low temperatures and suggested that cellular structure and composition may play a role in this impact. Fruit is usually stored in low-temperature conditions to slow physiologic metabolism, maintain quality, and extend storage life. (Jin Han *et al.*, 2006).

Role of mesa in pear

MeSA acts as a derivative of salicylic acid (SA) and has functions that are like those of SA. Only after being transformed back into SA does MeSA, a physiologically inert and mobile endogenous signal carrier, activate the defensive mechanism. Exogenous salicylates, such as SA, MeSA, and ASA (acetylsalicylic acid), have been widely used to improve fruit's biotic stress tolerance after harvest. Fruit can be treated with MeSA after harvest to delay ripening and senescence, improve color, appearance, texture, and other quality traits, and extend postharvest storability. Methyl salicylate could delay chlorophyll breakdown in the fruit (Huaiyu Zhang *et al.*, 2019).

Table 1: Methyl salicylate concentration Temperature

Crop	Methyl salicylate concentration	Temperature	Time	Effects	Citations
Banana	2mM	25 °C	6 days	Increase in Acerbate gliucotathine cycle and decrease spotting	Chotijakhan *et al.*, 2020
Pomegranate	0.1mM	20 °C	84 days	TAA in hydrophilic and lipophilic is deceased, lowered chilling injury, maintain Quality	Sayyari *et al.*,2010
Kiwi	32meu L	0 °C	100days	Limits lignin accumulation to some extent	Aghdam *et al.*, 2010 [24]
Sweet cherry	2mM	2 °C	20 days	Delay ripening ad maintain quality	Gimenez *et al.*, 2016 [12]
Mango	0.1mM	5 °C	28 days	Decrease in fresh firmness	Jin Han *et al.*, 2006

Role of salicylic acid in persimmon

At 2mM SA concentration, postharvest SA application on preserved persimmon fruit reduced disease incidence, however 1mM SA failed to prevent illnesses. SA had no effect on TSS, treatable acidity, soluble tannin concentration, or fruit firmness, according to the findings. In addition, when compared to the control, SA was unable to reduce ethylene output. SA treatment at a concentration of 2mM reduced the frequency of postharvest disease in persimmon fruit through an inducible defensive mechanism, making it suited for extending the fruit's postharvest life. (Khademi *et al.*, 2012) [19].

Role of salicylic acid in Plum

In plum, Chilling injury increased PPO and POD activity, which was linked to browning of the fruit flesh. Chilling injury was positively connected with putrescence and spermine contents in control fruit, which was accompanied by an increase in polyamine content. Reduced leakage, MDA content, delayed PPO and POD activities, and increased PA buildup were all linked to SA's suppression of chilling injury. SA therapy decreased respiration and ethylene production while delaying the climacteric peak of respiration. The findings show that SA treatment could be utilized commercially to prevent plum fruit from cooling during cold storage. (Zisheng *et al.*, 2011) [39].

Role of salicylic acid in pear

In pear, around 30, 60, and 90 days following full flowering, trees were sprayed three times with 2.5mM salicylic acid (SA). The fruit was picked when it reached commercial maturity (about 120 days after full blooming), inoculated with Penicillium expansum, and incubated at 20°C and 95–100% RH for two weeks. The SA sprays significantly increased resistance to the pathogen of mature pear fruit, on day 12 and 17 after incubation, disease incidence in SA-treated fruit was 58.0 percent or 26.5 percent lower, and lesion width was 58.4 percent or 29.0 percent smaller than in fruit without SA treatment (control). The findings imply that SA in the pear fruit may coordinately regulate enzymes that perform various activities. In fact, treating trees with SA sprays may give additional protection against postharvest disease of pear fruit, according to our findings, and might be utilized as an alternative and cost-effective way to reduce the usage of chemical fungicides (Jiankang Cao *et al.*, 2006).

Role of salicylic acid in pineapple

The 3.0- or 5.0-mM SA treatments reduced the internal browning (IB) index, while the 5.0mM SA treatment reduced soluble solids content (SSC), treatable acidity (TA), and soluble sugar content, but elevated ascorbic acid (AsA) levels at the end of shelf life. Overall, these findings show that post-harvest treatment with 5.0mM SA prevented IB in pineapple, increased its shelf life, and preserved fruit quality during cold storage (D.Q. Sun *et al.*, 2010).

Role of salicylic acid in kiwi

Salicylic acid (SA) levels in kiwifruit (Actinidia deliciosa (A. Chev.) CF Liang and AR Ferguson cv. Bruno) tissues decreased throughout postharvest ripening and softening at 20 degrees C. Lipoxygenase (LOX) activity increased at the same time, which was linked to climacteric ethylene emission. SA concentrations remained rather high in fruit held at 0 8C with a slower rate of softening. When acetylsalicylic acid

(ASA) was applied to ripening kiwifruit, the SA levels were much higher than in control fruit. The ripening and senescence of the fruit were also delayed. The extent of fruit ripening and softening was shown to be closely related to changes in SA levels in the fruit tissues (Yu Zhang 2002).

Role of salicylic acid in guava

In the tropical and subtropical zones, the guava fruit is one of the most popular fruits. Due to climacteric ripening and changes in physicochemical qualities, it is perishable and has a short postharvest shelf life at room temperature. After three periods of shelf life, SA at a concentration of 4mmol/L reduced TSS and WL. Guava fruit quality improved overall after postharvest treatment with SA solutions during shelf life. In treated guava fruit, there was a delay in ripening, reduced decay incidence, TSS, and weight loss WL, as well as improved qualitative attributes as compared to control (Arfat K.H 2019).

Role of salicylic acid in apple

SA therapy significantly boosted total antioxidant capacity (T-AOC) and defense-related enzyme activities, such as catalase (CAT), superoxide dismutase (SOD), peroxidase (POD), phenylalanine ammonia-lyase (PAL), and polyphenol oxidase (PPO) (PPO). Exogenous SA generated a rise in reactive oxygen species levels, and the antioxidant system could be responsible for increased resistance against G. cinnamomic in 'Gala' apple leaves, as expected. (Ying Zhang *et al.*, 2016).

Role of salicylic acid in mango

Every 7 days, researchers assessed chilling injury (CI) and ROS levels in the excerpt, including superoxide radical (O2), hydrogen peroxide (H2O2), and hydroxyl radical (HO). Total phenolic content, TAC, enzyme activities, and gene expression of SOD, CAT, and APX increased during storage with a decrease in ascorbic acid and total glutathione contents, while total phenolic content, TAC, enzyme activities, and gene expression of SOD, CAT, and APX increased during the first 21 days of storage but gradually decreased thereafter. On day 21, CI symptoms appeared in the control fruits and quickly progressed. The antioxidant defense mechanism is strengthened by SA treatment, which reduces CI in mango fruits during cold storage (Chanikan Junmatong *et al.* 2015) [18].

Role of salicylic acid in peach

When compared to other treatments, including control, SA at 2.0mmol L-1 concentration showed considerably reduced weight loss, greater flesh stiffness, increased SSC, higher TA contents, higher skin brightness, and decreased a value. As a result, during five weeks of storage, SA at 2.0mmol L-1 concentration showed a considerable rise in ascorbic acid and total phenolics content, but relative electrical conductivity was lowered. As a result, the current findings imply that SA at a concentration of 2.0mmol L-1 could be utilized commercially to preserve peach fruits for up to five weeks without deterioration. (M.J. Tareen *et al.*, 2012) [35].

Role of salicylic acid in banana

Chilling damage was caused by a low temperature (6 °C), and metabolites such as glutamine, serine, and glucose were linked to chilled bananas. The disaccharides increased by 18.1–21.4 percent after SA released the cold damage. The production of unsaturated fatty acids and amino acids like praline, as well as an increase in energy charge as a result, SA enhanced freezing tolerance through a variety of metabolic processes (Lin Chen *et al.*, 2020).

Role of salicylic acid in grapes

Harvested clusters of 'Thompson Seedless', or in Iran, were treated with SA at four concentrations: 0, 1, 2, and 4mM, then stored at 0 °C for 45 days before being exposed for two days at 20 °C to determine their shelf life. Water loss, fungal degradation, and the softened berry rate were all reduced by all three SA concentrations. SA at a dosage of 4mM was found to be beneficial in preventing the spread of decay infection. SA at doses of 2 and 4mM considerably slowed the browning of the rachis. The application of SA to grape berries after harvest has the potential to extend the shelf life of table grapes while maintaining their quality. (Ehsan Ranjbaran 2011) [29].

Role of salicylic acid in papaya

Papaya fruit being perishable, and climacteric are highly susceptible to fungal attack resulting in fruit decay and lesser shelf life. Salicylic acid (SA) can preserve the quality of fruit by suppressing decay incidence and increasing antioxidative enzyme activities. (Alia Hanif *et al.*, 2020) [14].

Table 2: Show Concentration Temperature Time

Crop	Concentration	Temperature	Time	Effects	Citations
Pear	2.5mM	20 °C	120 days	Spray gives addition protection against postharvest diseases	Jiankang Cao *et al.*, (2006)
Pineapple	5mM	10 °C	20 days	Degradation of starch	D.Q. Sun *et al.*, (2010)
Kiwi	5mM	0 °C	105 days	extension of fruits ripening and softing	Yu Zhang (2002)
Guava	4mol/L	25 °C	25 days	Decay incidence decreased, TSS and weight loss	Arfat K.H (2019)
Apple	0.2mM	24 °C	8 days	Triggered increase in reactive oxygen species levels	Ying Zhang *et al.*, (2016)
Mango	1mM	5-+1 °C	42 days	Antioxidant defense mechanism is strengthened, reduces chilling injury	Chanikan Junmatong *et al.*, (2015)
Peach	2mM	0 °C	35 days	Higher TA concentration less weight loss, higher flesh firmness	M.J. Tareen *et al.*, (2012) [35]
Banana	500mM	15 °C	6 days	Improved EC of cold stored bananas and increase chilling tolerance	Lin Chen *et al.*, (2020)
Grape	4mM	0 °C	45 days	Extend shelf life of grape berries	Ehsan Ranjbaran (2011) [29]
Papaya	1.5mM	12 °C	28days	Extending of shelf life and decay incidence, maintaining firmness	Aliya Hanif *et al.*, 2020 [14]

Conclusion

SA and Mesa treatments boost postharvest chilling injury resistance in horticultural crops. In this review paper discussed on various managements done after harvesting of different horticultural crops by application of methyl salicylate and salicylic acid. Results shows the prolongation of storage period is observed and with low antifungal activity after the application of these chemicals. Used mostly for the extension of shelf life in fruits. And for the extension of fruits ripening and softening. Overall the study suggests that the chemicals MeSA and SA shows effective results in post-harvest application in fruit crops.

References

1. Amiri S, Nicknam Z. Radi Postharvest quality of orange fruit as influenced by salicylic acid, acetic acid, and carboxymethyl cellulose coating. Food Measure. 2021;15:3912–3930. https://doi.org/10.1007/s11694-021-00966-y.
2. Arafat KH. Improved the shelf life of guava fruits by salicylic acid against postharvest black spot disease. Journal of Plant Protection and Pathology. 2019;10(4):237-243.
3. Asghari M, Ahadis L, Riaie S. Effect of salicylic acid and edible coating-based aloe vera gel treatment on storage life and postharvest quality of grape (Vitis vinifera L. cv. Gizel Uzum). Inter J Agric Crop Sci. 2013;5:2890-98.
4. Asghari M. Effects of salicylic acid on Selva strawberry fruit, antioxidant activity, ethylene production and senescence, fungal contamination, and some other quality attributes. University of Tehran, 2006, 4.
5. Asghari M, Aghdam MS. Impact of salicylic acid on post-harvest physiology of horticultural crops. Trends in Food Science & Technology. 2010;21(10):502-509.
6. Asghari MR, Hajitagilo R, Shirzad H. Postharvest treatment of salicylic acid effectively controls pear fruit diseases and disorders during cold storage. In: Proceedings of the international congress on Novel approaches for the control of postharvest diseases and disorders cost action. 2007;924:355-360.
7. Cao J, Zeng K, Jiang W. Enhancement of postharvest disease resistance in Ya Li pear (*Pyrus bretschneideri*) fruit by salicylic acid sprays on the trees during fruit growth. European Journal of Plant Pathology. 2006;114(4):363-370.
8. Chen L, Zhao X, Wu JE, He Y, Yang H. Metabolic analysis of salicylic acid-induced chilling tolerance of banana using NMR. Food Research International. 2020;128:108796.66
9. Gimenez MJ, Valverde JM, Valero D, Zapata PJ, Castillo S, Serrano M. Postharvest methyl salicylate treatments delay ripening and maintain quality attributes and antioxidant compounds of 'early Lory' sweet cherry. Postharvest Biology and Technology. 2016;117:102-109.
10. Hakimeh Mansouri. Salicylic acid and sodium nitroprusside improve postharvest life of chrysanthemums, Sciatica Horticulture. 2012;145:29-33.
11. Hanif A, Ahmad S, Shahzad S. *et al.* Postharvest application of salicylic acid reduced decay and enhanced storage life of papaya fruit during cold storage. Food Measure. 2020;14:3078–3088. https://doi.org/10.1007/s11694-020-00555-5
12. Hua Li, Jiangtao Suo, Ye Han, Chunqiang Liang, Mijing Jin, Zhengke Zhang, *et al.* The effect of 1-methylcyclopropene, methyl Jasmonate and methyl salicylate on lignin accumulation and gene expression in postharvest 'Xinxiang' kiwifruit during cold storage, Postharvest Biology and Technology. ISSN: 0925-5214, 2017;124:107-118. DOI: https://doi.org/10.1016/j.postharvbio.2016.10.003.
13. Huaiyu Zhang, Lunaike Zhao, Chunxia Fan, Peng Wang, Meili Cui, Lina Liu, *et al.* Impact of methyl salicylate on storage quality, ethylene action and protein profiling of 'Zaosu' pear (*Pyrus bretschneideri*), Sciatica Horticulture. 2020;264:109-196. DOI: 10.1016/j.scienta.2020.109196
14. Huang RH, Liu JH, Lu YM, Xia RX. Effect of salicylic acid on the antioxidant system in the pulp of 'Cara Cara' navel orange (Citrus Sinensis L Osbeck) at different storage temperatures. Postharvest Biology and Technology. 2008;47(2):168-175.
15. Junmatong C, Faiyue B, Rotarayanont S, Uthaibutra J, Boonyakiat D, Saengnil K. Cold storage in salicylic acid increases enzymatic and non-enzymatic antioxidants of Nam Dok Mai No 4 mango fruit. Science Asia. 2015;41(12):12-21.
16. Khademi O, Zamani Z, Mostofi Y, Kalantari S, Ahmadi A. Extending storability of persimmon fruit cv. Karaj by postharvest application of salicylic acid. Journal of Agricultural Science and Technology (JAST). 2012;14(5):1067-1074.
17. Libin Wang, Elizabeth A Baldwin, Anne Plotto, Weiqi Luo, Smita Raithore, Zhifang Yu, *et al.* 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.
18. Liu Z, Ding Y, Wang F, Ye Y, Zhu C. Role of salicylic acid in resistance to cadmium stress in plants. Plant cell Reports. 2016;35(4):719-731.
19. Lu XH, Sun DQ, Mo YW, Xi JG, Sun GM. Effects of post-harvest salicylic acid treatment on fruit quality and antioxidant metabolism in pineapple during cold storage. The Journal of Horticultural Science and Biotechnology. 2010;85(5):454-458.
20. Luo Z, Chen C, Xie J. Effect of salicylic acid treatment on alleviating postharvest chilling injury of 'Qingnai' plum fruit. Postharvest Biology and Technology. 2011;62(2):115-120.
21. Mohammadreza Asghari, Morteza Soleimani Aghdam. Impact of salicylic acid on post-harvest physiology of horticultural crops, trends in food science & technology. ISSN: 09242244, 2010;21:502-509.
22. Popova L, Pancheva T, Uzunova A. Salicylic acid: properties, biosynthesis, and physiological Role. Bulg. J Plant Physiol. 1997;23(1-2):85-93.
23. Rangel-Sánchez G, Castro-Mercado E, García-Pineda E. Avocado roots treated with salicylic acid produce phenol-2, 4-bis (1, 1-dimethylethyl), a compound with antifungal activity. Journal of plant physiology. 2014;171(3-4):189-198.
24. Ranjbaran E, Sarikhani H, Wakana A, Bakhshi D. Effect of salicylic acid on storage life and postharvest quality of grape (Vitis viniferous L. *cv.* Bidaneh Sefid), 2011.
25. Raskin I, Skubatz H, Tang W, Meeuse BJ. Salicylic acid levels in thermo genic and non-thermo genic plants. Annals of Botany. 1990;66(4):369-373.
26. Sayyari M, Valero D, Babalar M, Kalantari S, Zapata PJ, Serrano M. Prestorage oxalic acid treatment maintained visual quality, bioactive compounds, and antioxidant

potential of pomegranate after long-term storage at 2C. Journal of Agricultural and Food Chemistry. 2010;58(11):6804-6808.9.

27. Shi GR, Cai QS, Liu QQ, Wu L. Salicylic acid-mediated alleviation of cadmium toxicity in hemp plants in relation to cadmium uptake, photosynthesis, and antioxidant enzymes. Acta Physiologies Plant Arum. 2009;31(5):969-977.
28. Sirawich Chotikakham, Aussara Panya, Kobkiat Saengnil. Methyl salicylate treatment alleviates peel spotting of 'Sucrier' banana by improving mitochondrial physiological properties and functions, Postharvest Biology and Technology. ISSN: 0925-5214, 2022;186:111-832
DOI: https://doi.org/10.1016/j.postharvbio.2021.111832.
29. Srivastava MK, Dwivedi UN. Delayed ripening of banana fruit by salicylic acid. Plant Science. 2000;158(1-2):87-96.
30. Tareen MJ, Abbasi NA, Hafiz IA. Effect of salicylic acid treatments on storage life of peach fruits *cv.* 'Flordaking'. Pakistan Journal of Botany. 2012;44(1):119-124.
31. Zhang Y, Chen K, Zhang S, Ferguson I. The role of salicylic acid in postharvest ripening of kiwifruit. Postharvest Biology and Technology. 2003;28(1):67-74.
32. Zhang Y, Shi X, Li B, Zhang Q, Liang W, Wang C. Salicylic acid confers enhanced resistance to Glomerella leaf spot in apple. Plant Physiology and Biochemistry. 2016;106:64-72.
33. Zhao XY, Qi CH, Jiang H, Zhong MS, You CX, Li YY, *et al.* MdWRKY15 improves resistance of apple to Botryosphaeria dothidea via the salicylic acid-mediated pathway by directly binding the MdICS1 promoter. Journal of integrative plant biology. 2020;62(4):527-543.
34. Zisheng Luo, Chun Chen, Jing Xie, Effect of salicylic acid treatment on alleviating postharvest chilling injury of 'Qingnai' plum fruit, Postharvest Biology and Technology, ISSN: 0925-5214, 2011;62(2):115-120.