www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(9): 42-51

www.thepharmajournal.com
Received: 10-07-2023
Accepted: 14-08-2023

Apsara BU
PG Scholar, Department of Fruit Science, Dr. YSRHU College of Horticulture, Venkataramannagudem, West Godavari, Andhra Pradesh, India

M Madhavi
Associate Dean, Professor & Head, Department of Fruit Science, Dr. YSRHU College of Horticulture, Venkataramannagudem, West Godavari, Andhra Pradesh, India

P Vinaya Kumar Reddy
Assistant Professor, Department of Fruit Science, Dr. YSRHU College of Horticulture, Venkataramannagudem, West Godavari, Andhra Pradesh, India

P Subbaramamma
Associate Professor, Department Plant physiology, Associate Professor, Department of Plant physiology, Dr. YSRHU College of Horticulture, Venkataramannagudem, West Godavari, Andhra Pradesh, India

V Shekhar
Assistant Professor (Statistics) Department of ESSC (English, Statistics and Social Sciences) College of Horticulture, Venkataramannagudem, West Godavari, Andhra Pradesh, India

Corresponding Author:
Apsara BU
PG Scholar, Department of Fruit Science, Dr. YSRHU College of Horticulture, Venkataramannagudem, West Godavari, Andhra Pradesh, India

Influence of pre-harvest elicitors sprays on quality attributes and shelf life of papaya (*Carica Papaya* L.) cv. red lady

Apsara BU, M Madhavi, P Vinaya Kumar Reddy, P Subbaramamma and V Shekhar

Abstract
The present investigation, "Influence of preharvest elicitors sprays on quality attributes and shelf life of papaya (*Carica Papaya* L.) cv. Red Lady was carried out at Department of Fruit Science, Dr. YSRHU-College of Horticulture, Venkataramannagudem, West Godavari district of Andhra Pradesh during 2022-23. The experiment was laid out in a Completely Randomized Design (CRD) with five treatments and each treatment replicated thrice. Four different preharvest elicitors spray *viz.*, Brassinosteroid @ 0.1%, Salicylic acid @ 300 ppm, Chitosan @ 1.5%, Benzyl Adenine @ 50 ppm and control (no sprays). The preharvest elicitors sprays were given twice (one month and 15 days before harvest) when the fruits are in immature stage. The performance of preharvest elicitors sprays on quality and shelf life of papaya fruits was studied at 3 days intervals. The results revealed that fruits harvested from the plants sprayed with preharvest elicitors salicylic acid @ 300 ppm had showed significant improvement in quality attributes *viz.*, less reduction in physiological loss in weight (8.35%), least percent of fruit spoilage (40.00%), maximum in fruit firmness (9.90 kg cm^{-2}), TSS (11.40 °Brix), total sugars (9.89%), reducing sugars (5.94%), non-reducing sugars (3.90%), β-carotene content (1.06 mg 100 g^{-1}), titrable acidity (0.285%), ascorbic acid (75.30 mg 100 g^{-1}), total antioxidants (69.02% DPPH activity), catalase (0.84 units/mg protein/min) and peroxidase activities (0.81 units/mg protein/min) and shelf life (10.68d) of papaya fruit as compared to other treatments at 9th day of storage.

Keywords: Papaya, preharvest elicitors, sugars, antioxidants and shelf life

Introduction
Papaya (*Carica papaya* L.) is regarded as the wonder fruit of the tropical and sub-tropical regions of the world. It belongs to the family Caricaceae with a chromosomal number 2n=18. Papaya is also known as paw-paw and tree melon. It is a dicotyledon, polygamous and diploid species with a geographical origin of Southern Mexico and Costa Rica (Candolle, 1884) [6].
Papaya is domesticated in both tropical and sub-tropical regions of the world (Asia, Africa, Oceania, and North America). India is the largest producer of papaya (cultivated area of 1.48 lakh Ha as well as annual production of 58.85 lakh MT) in the world followed by Brazil, Mexico, Indonesia and Nigeria, whereas the United States is largest consumer of papaya in the world. In Andhra Pradesh, papaya is cultivated in an area of 15.82 thousand hectares with a production of 1503.19 thousand tonnes, it contributes to a lion share of 26.17% followed by Gujarat, Maharashtra and Karnataka. It is growing mainly in Chittoor, Ananthapuramu, Kadapa, Prakasam, and Vizianagaram districts of Andhra Pradesh (Anonymous, 2022) [2].
Papaya fruits exhibit a climacteric ripening behaviour and has a very short storage life under ambient conditions. Even though there is a large production of papaya among all the fruits grown in India, a major portion estimated around 40-60% of the total production goes into waste due to its perishable nature at various papaya growing regions. The major causes for post-harvest losses in papaya are improper harvesting, storage, packaging, transportation, mishandling of the fruits and attack of post-harvest diseases (Prasad and Paul, 2021) [25]. Hence, proper postharvest storage strategies are required to incorporate and the concern about food safety and nutritional security among the consumers as well as best returns to the farmers, agro-industries encourage the research to find safe and sustainable alternative chemicals to reduce the postharvest losses as well as maintaining quality of papaya fruits throughout the prolonged storage period.

The preharvest elicitors application may delay the senescence in fruits without causing any detrimental effect on consumer acceptance. Elicitors plays a vital role in maintaining the quality and shelf life of the fruits by interfering with the biosynthesis and action of ethylene through the suppression of ACC synthase and ACC oxidase activities. Preharvest elicitors spray may decrease the activities of major cell wall degrading enzymes such as cellulase, polygalacturonase, PME and xylanase and thereby controlling the physiological loss in weight and maintains the fruit firmness. It also reduces the lipid peroxidation and enhances the enzymatic and non-enzymatic antioxidant production thereby control the release of free radicals. Preharvest elicitors may stimulate the production of enzymes and encodes some of the defence related genes, which induce resistance (indirect mechanism) through production of secondary metabolites as well as the formation of different phenolic compounds that are toxic to fungi (direct mechanism) (Zhao *et al.*, 2005) [44]. Hence, the use of preharvest elicitors in present investigation is a best approach in maintenance of quality and improvement of fruit shelf life by controlling the postharvest losses and fetches more income to the farmers.

Materials and Methods

The present investigation, "Influence of preharvest elicitors sprays on quality attributes and shelf life of papaya (*Carica Papaya* L.) cv. Red Lady was carried out at Department of Fruit Science, Dr. YSRHU-College of Horticulture, Venkataramannagudem, West Godavari district of Andhra Pradesh during 2022-23. The experiment was laid out in Completely Randomized Design (CRD) with five treatments and each replicated thrice. In this study, four different preharvest elicitors spray *viz.*, Brassinosteroid @ 0.1%, Salicylic acid @ 300 ppm, Chitosan @ 1.5% and Benzyl Adenine @ 50 ppm were used along with control (no sprays). Five plants of one year old, uniform size were selected in each replication and were tagged. Preharvest elicitors sprays were started at 30 and 15 days before harvest of the fruits *i.e.*, at immature stage of fruits. Spraying was done with the help of hand sprayer.

The pre-harvest elicitors spray solutions of Brassinosteroid @ 0.1% (dissolving 1 ml of Brassinosteroid in water and the volume was made up to 1000 ml). Salicylic acid @ 300 ppm and Benzyl Adenine solution @ 50 ppm were prepared by dissolving 300 mg of Salicylic acid 50 mg of Benzyl Adenine respectively in 0.l N NaOH separately with the help of magnetic stirrer and volume was made up to 1000 ml with water. The Chitosan at 1.5% solution was prepared by dissolving 1.5 g of Chitosan in 0.5% glacial acetic acid and volume was made up to 100 ml with distilled water.

Fruits were harvested at maturity when the colour of fruit peel changes from dark green to well-defined yellow stripes and were labelled according to different treatments. The fruits were wrapped with a paper to prevent the mechanical injury and transportation shocks. The performance of elicitors sprays on quality attributes and shelf life of papaya was studied at 3 days intervals.

The physiological loss in weight of the fruits in each treatment was recorded at three days interval and subtracted from the initial weight. The loss of weight in grams in relation to initial weight was calculated and expressed as percentage. The fruit firmness was determined by using fruit tester penetrometer and expressed in kgcm^{-2} as per the procedure outlined by Saini *et al.* (2006) [29]. The fruits were visually observed during storage for spoilage and the number of spoiled fruits in the total fruits was determined and spoilage ratios were calculated as percentage. The total soluble solids (TSS) were determined by using hand refractometer. The total, reducing and non-reducing sugars were estimated as per the procedure described by Lane and Eyon (AOAC, 1965) [18] method. The titrable acidity in fruit pulp was determined by titrating the sample extracted in water against 0.1N NaOH as described by Ranganna (1986) [27]. The non-enzymatic antioxidants *viz.*, β-carotene and ascorbic acid were estimated as per the procedures described by Ranganna *et al.* (1986) [27]. The enzymatic antioxidants *viz* catalase and peroxidase and total antioxidant activities were estimated as per the procedures described by Luck (1974) [19]; Mallik and Singh (1980) [20] and Eghdami and Sadeghi (2010) [10] respectively.

Results and Discussion

Physical Parameter

Physiological loss in weight (%)

The data on influence of preharvest elicitors sprays on physiological loss in weight was presented in Table-1. The physiological loss in weight was increased gradually from upto 9th day after storage in all the treatments. The minimum percent weight loss was recorded in Salicylic acid @ 300 ppm (S_2) treatment from 3rd to 9th day after storage (4.27% to 8.35%) followed by Chitosan @ 1.5% treatment (S_3) from 3rd to 9th day after storage (4.60% to 8.75%) whereas, the maximum physiological loss in weight was recorded in unsprayed (control) fruits (S_5) from 3rd to 9th day after storage (6.28% to 12.99%). Salicylic acid treatment had significantly reduced the physiological loss in weight of fruits might be due to decrease in transpiration as well as respiration rates (Singh and Tiwari, 1994) [32]. Similar results were reported by Zhang and Zheng (2004) [42] in 'ponkan' mandarin; Venu *et al.* (2016) [36] in guava; Devarkonda *et al.* (2020) [7] and Kavya *et al.* (2022a) [15] in papaya cv. Red Lady.

Fruit firmness (kg cm^{-2})

The data collected on effect of preharvest elicitors sprays on fruit firmness was shown in Table-2. The fruit firmness was decreased significantly in all the treatments as storage period advanced. The fruit firmness was more in all the pre harvest elicitors treatments as compared to unsprayed fruits during ambient storage condition. However, fruits sprayed with Salicylic acid @ 300 ppm (S_2) had retained significantly the maximum fruit firmness (11.69 kg cm^{-2} to 9.90 kg cm^{-2} from 3rd to 9th day of storage respectively) followed by Chitosan @ 1.5% (S_3) (11.22 kg cm^{-2} to 9.46 kg cm^{-2} from 3rd to 9th day of storage respectively). The minimum fruit firmness was recorded in unsprayed fruits (9.20 kg cm^{-2} to 7.50 kg cm^{-2} from 3rd to 9th day of storage respectively). Softening of papaya fruits were remarkably delayed with the preharvest elicitors spray *i.e.*, Salicylic acid @ 300 ppm might be due to decrease in the activity of cell wall degrading enzymes through regulation of ethylene production. The results are in agreement with the findings of Srivastava and Dwivedi (2000) [34] in banana; Asghari and Aghdam (2010) [3] in peach; Devarkonda *et al.* (2020) [7] and Kavya *et al.* (2022a) [15] in papaya cv. red lady.

Fruit spoilage (%)

The data pertaining to percent fruit spoilage was presented in

Table-3. Preharvest elicitors sprays had significantly reduced the percent fruit spoilage. No fruit spoilage (0%) was recorded at 3rd day of storage in fruits harvested from the plants treated with Salicylic acid @ 300 ppm (S_2) and Chitosan @ 1.5% (S_3) whereas maximum (24.45%) percent of fruit spoilage was recorded in fruits harvested from the plants without any elicitors spray. The lowest percent fruit spoilage was recorded at 6th (6.67%) and 9th (40.00%) day after storage in fruits harvested from the plants treated with salicylic acid @ 300 ppm (S_2) followed by Chitosan @ 1.5% (S_3) at 6th (8.89%) and 9th (46.67%) day after storage. The highest percent fruit spoilage was recorded in fruits without any elicitors spray at 6th (37.78%) and 9th (75.56%) day after storage. Salicylic acid shows direct toxic effect on fungi and significantly inhibits the fungal growth and pathogen spore germination *in vitro.* Salicylic acid might had reduced the lesion diameter on fruits by upregulation of genes encoding for β-1,3-glucanase and phenylalanine ammonia-lyase (PAL) activities during storage. Preharvest application of salicylic acid may provide a useful means of controlling postharvest decay by reducing microbial growth as well as ethylene production there by extending the storage life fruits (Wang and Shaohua, 2008) [37]. Similar results were reported by Devarkonda *et al.* (2020) [7] and Kavya *et al.* (2022a) [15] in papaya cv. red lady.

Biochemical Parameters

Titrable acidity (%)

The data on influence of preharvest elicitors sprays on titrable acidity of papaya cv. Red Lady fruits was presented in Table-4. Significant differences were noticed among the treatments for titrable acidity at all intervals of storage. The data depicted that titrable acidity showed a consistant decline among treated fruits as storage period advances. The maximum titrable acidity was maintained in fruits sprayed with Salicylic acid @ 300 ppm (S_2) treatment at 3rd (0.388%), 6th (0.347%) and 9th (0.285%) day of storage, while minimum was recorded in unsprayed fruits (S_5) at 3rd (0.322%), 6th (0.248%) and 9th (0.190%) day of storage. Salicylic acid treatment had maintained the highest titrable acidity during storage interval might be due to less metabolic activities *i.e.*, slow conversion of acids into sugars has led to delay in ripening and thereby increased the fruit shelf life. Similar results were reported by Martínez-Esplá *et al.* (2017) [22] in plum; Orabi *et al.* (2018) [24] in mandarin and Hanif *et al.* (2020) [11] in papaya and Devarkondanda *et al.* (2020) [7].

Total soluble solids (° Brix)

The data on total soluble solids in papaya cv. red lady fruit pulp was shown in Table-5. A gradual increase in total soluble solids were noticed all the treated and untreated fruits during the storage later showed a decreasing trend. At 3rd day after storage, the total soluble solids were maximum in fruits harvested from the plants sprayed with Salicylic acid @ 300 ppm (S_2) (8.87 ºBrix) which was on par with Chitosan @ 1.5% treatment (8.71 ºBrix) and the minimum (8.34 ºBrix) TSS was in brassinosteroid @ 0.1% (S_1) treatment. At 6th day of storage, the highest total soluble solids (10.36 ºBrix) were recorded in fruits without any elicitors spray (S_5) treatment followed by fruits harvested from the plants applied with Salicylic acid @ 300 ppm (S_2) (10.10 ºBrix) and the least TSS (9.45 ºBrix) was recorded in fruits harvested from the plants treated with Benzyl Adenine @ 50 ppm (S_5). At 9th day of storage, the highest total soluble solids (11.40 ºBrix) were recorded in fruits harvested from the plants sprayed with Salicylic acid @ 300 ppm (S_2) followed by Chitosan @ 1.5% (S_3) treatment (11.12 ºBrix) whereas the lowest TSS (10.20 ºBrix) was recorded in fruits taken from the plants without elicitors spray (S_5).

Total sugars (%)

The data pertaining to percent total sugars in papaya cv Red Lady fruit pulp was presented in Table-6. Significant differences were noticed among the treatments for percent total sugars. The percent total sugars were gradually increased from 3rd to 9th day of storage later showed a decreasing trend. The percent total sugars were high (7.55%) in fruits harvested from the plants sprayed with Salicylic acid @ 300 ppm (S_2) followed by Chitosan @ 1.5% (S_3) treatment (7.25%) and low (7.01%) in fruits harvested from the plants without any preharvest elicitors spray (control) treatment at 3rd day of storage. The percent total sugars were high (8.21%) in fruits harvested from the plants without any elicitors spray followed by Salicylic acid @ 300 ppm (S_2) treatment (8.14%) and low (7.62%) in fruits harvested from the plants sprayed with preharvest elicitors Benzyl Adenine @ 50 ppm (S_4) treatment at 6th day of storage. At 9th day of storage, the percent total sugars were more (9.89%) in fruits harvested from the plants sprayed with preharvest elicitors Salicylic acid @ 300 ppm (S_2) treatment followed by (Chitosan @ 1.5%) S_3 treatment (9.66%) and the percent total sugars were found less (8.76%) in fruits harvested from the plants without any preharvest elicitors spray (control) treatment (S_5).

Reducing sugars (%)

The data (Table-7) showed significant differences with pre harvest elicitors spray on percentage of reducing sugars in papaya fruit. The trend was alike to total sugars content. At 3rd day of storage, the maximum reducing sugars content (4.66%) was found in fruit harvested from the plants sprayed with Salicylic acid @ 300 ppm (S_2) and minimum (4.33%) was found in Benzyl Adenine @ 50 ppm (S_4) and fruits without any elicitors sprays (S_5) (4.35%). At 6th day of storage, among preharvest sprays the high reducing sugars content (4.96%) was found in unsprayed fruits (S_5) and low reducing sugars of 4.50% was found in fruits sprayed with Benzyl Adenine @ 50 ppm (S_4). At the 9th day of storage, maximum percentage of reducing sugars (5.94%) was recorded in S_2 (Salicylic acid @ 300 ppm) which was on par with S_3 (Chitosan @ 1.5%) (5.73%) and minimum was noticed in S_5 (unsprayed fruits) (5.10%).

Non-Reducing sugars (%)

The data in respect of percentage of non-reducing sugars are presented in the Table-8. It showed that the treatments had significant influence on percentage of non-reducing sugars. The trend was alike to total sugars content. At 3rd day of storage, the highest percentage of non-reducing sugar (2.72%) was found in Salicylic acid @ 300 ppm (S_2) whereas, fruits with no elicitors sprays (S_5) recorded lowest non-reducing sugar percentage (2.32%). At 6th day of storage, Salicylic acid @ 300 ppm (S_2) (3.28%) recorded maximum non-reducing sugars content which was on par with unsprayed fruits (S_5) (3.24%) and minimum was observed in Benzyl Adenine @ 50 ppm (S_4) (3.12%). At 9th day of storage showed that maximum non-reducing sugars (3.90%) in fruit harvested from fruits sprayed with S_2 (Salicylic acid @ 300 ppm) which was on par with Chitosan @ 1.5% (S_3) (3.83%), and minimum (3.50%) in S_5 (unsprayed fruits).

There was a gradual increase in TSS, total sugars, reducing sugars and non-reducing sugars in fruits harvested from the plants sprayed with Salicylic acid @ 300 ppm might be due to slowed down of the activities of hydrolytic enzymes involved in starch hydrolysis by suppression of ethylene biosynthesis and thereby delayed the ripening process. Similar results were reported by Singh *et al.* (2001) [33] in mango; Devarkonda *et al.* (2020) [7] and Hanif *et al.* (2020) [11] in papaya.

β- Carotene content (mg 100 g^{-1})

The data on β-carotene content of papaya fruits as influenced by the application of preharvest elicitors sprays was presented in Table-9. Significant differences were found among the treatments. The β-carotene content was increases as the advancement of storage period and decreases later on. It was found that there was a rapid increase in β-carotene content in untreated fruits upto 6th day of storage and declines thereafter. The minimum β-carotene content was recorded in fruits harvested from the plants sprayed with Chitosan @ 1.5% (S_3) treatment from 3rd (0.58 mg 100 g^{-1}) to 9th (1.05 mg 100 g^{-1}) day of storage which was on par with β-carotene content in fruits harvested from the plants sprayed with salicylic acid @ 300 ppm (S_2) treatment from 3rd (0.59 mg 100 g^{-1}) to 9th (1.06 mg 100 g^{-1}) day of storage. The maximum β-carotene content was observed in unsprayed fruits at 3rd (0.74 mg 100 g^{-1}) to 6th (1.04 mg 100 g^{-1}) day of storage while the fruits sprayed with Benzyl Adenine @ 50 ppm (S_4) treatment had showed the maximum (1.11 mg 100 g^{-1}) β-carotene content at 9th day of storage. The plants sprayed with preharvest elicitors Chitosan @ 1.5% percent had recorded the lowest β-carotene content (1.05 mg 100 g^{-1}) in fruit pulp as compared to other preharvest elicitors sprays might be due to suppression of ethylene biosynthesis as well as slower degradation of chlorophyll content in fruit peel during storage. Similar results were reported by Barrera *et al.* (2015) [5] in papaya; Zoran *et al.* (2008) [45] in bell pepper and Kavya *et al.* (2022b) [16] in papaya.

Ascorbic acid (mg 100 g^{-1})

The data on ascorbic acid content of papaya fruit pulp as influenced by the different preharvest elicitors sprays was presented in Table-10. Ascorbic acid content showed a declining trend with an increase in storage period. The maximum ascorbic acid content was recorded in fruits of plants sprayed with Salicylic acid @ 300 ppm (S_2) from 3rd (91.50 mg 100 g^{-1}) to 9th (75.30 mg 100 g^{-1}) day of storage followed by Chitosan @ 1.5% (S_3) from 3rd (90.40 mg 100 g^{-1}) to 9th (74.76 mg 100 g^{-1}) and minimum ascorbic acid content was noticed in fruits harvested from the plants without any elicitors (S_5) treatment from 3rd (84.59 mg 100 g^{-1}) to 6th (70.31 mg 100 g^{-1}) day of storage. In the present investigation, there was a gradual decline in ascorbic acid content of the fruit pulp irrespective of the treatments during the storage period. The loss in ascorbic acid content during storage might be due to its degradation during metabolic processes or due to enzymatic oxidation of L-ascorbic acid into dehydro ascorbic acid (Mapson, 1970) [21]. The highest ascorbic acid content was found in fruit pulp of Salicylic acid treated fruits could be due to control of oxidative degradation of ascorbic acid during fruit ripening thereby reduced the production of reactive oxygen species (Jimenez *et al.*, 2002) [13]. Similar observations were reported by Karlidag *et al.* (2009) [14] and Salari *et al.* (2012) [30] in strawberry, Ardakani *et al.* (2013) [2] in apricot; Khademi and Ershadi, (2013) in peach; Venu *et al.* (2016) [36] in guava cv. Allahabad safeda and Devarkonda *et al.* (2020) [7] in papaya cv. "Red Lady".

Catalase activity (units/mg protein/min)

The perusal of data presented in Table-11 and Fig-1 reveals that significant differences were found among the treatments for catalase (CAT) activity in papaya cv Red Lady fruit under ambient conditions. Catalase activity was gradually increased upto 9th day of and declined thereafter in treated fruits whereas in untreated fruits the catalase activity was increased rapidly up to 6th day of storage and declines thereafter. The catalase activity was lowest in Salicylic acid @ 300 ppm (S_2) treatment (0.38 and 0.68 units/mg protein/min at 3rd and 6th day of storage respectively) followed by Chitosan @ 1.5% (S_3) treatment (0.47 and 0.72 units/mg protein/min at 3rd and 6th day of storage respectively) whereas unsprayed fruits (S_5) had recorded the highest catalase activity (0.64 and 0.82 units/ mg protein/ min at 3rd and 6th day of storage respectively). Further, at 9th day of storage the highest catalase activity was recorded in Salicylic acid @ 300 ppm (S_2) treated fruits (0.84 units/mg protein/min) followed by Chitosan @ 1.5% (S_3) treatment (0.80 units/mg protein/ min) while the lowest catalase activity (0.68 units/mg protein/min) was recorded in unsprayed fruits (S_5).

Peroxidase activity (units/mg protein/min)

The data on influence of preharvest elicitors sprays on peroxidase (POD) activity in papaya cv. Red Lady fruit pulp was shown in Table-12 and Fig-2. Significant differences were noticed among the treatments. The peroxidase activity was gradually increased from initial to 9th day of storage for the treated fruits and declined thereafter whereas in untreated fruits, there was a rapid increase in peroxidase activity up to 6th day of storage and gradually decreased as the storage period advanced. The peroxidase activity was low (0.37 and 0.63 units/mg protein/min at 3rd and 6th day of storage respectively) in fruits harvested from the plants treated with salicylic acid @ 300 ppm (S_2) treatment. The peroxidase activity was high (0.48 and 0.91 units/mg protein/min at 3rd and 6th day of storage respectively) in unsprayed fruits (S_5) treatment. Further, at 9th day of storage, the peroxidase activity was maximum (0.81 units/mg protein/min) in Salicylic acid @ 300 ppm (S_2) sprayed fruits, while the minimum (0.71 units/ mg protein/ min) was noticed in unsprayed fruits (S_5).

The Salicylic acid treatment could maintain the higher levels of non-enzymatic antioxidants *viz.*, gradual increase in β-carotene (1.06 mg 100 g^{-1}), higher levels of ascorbic acid content (75.30 mg 100 g^{-1}), enzymatic antioxidants *viz.*, catalase (0.84 units/mg protein/min) and peroxidase (0.81 units/mg protein/min) enzyme activities and total antioxidants (69.02% DPPH activity) might prevent the lipoxygenase (LOX) activity, production of oxygen free radicals (ROS) thereby slow down the ethylene biosynthesis and respiration rate during early stages of fruit ripening (Zhang *et al.*, 2003 and Ding and Wang, 2003) [43, 8]. Salicylic acid could protect the cell from damage at earlier stages of fruit development, thus enhanced the shelf life by regulating the balance between production and degradation of ROS. Similar results of increase in catalase and peroxidase enzyme activities were reported by Wang and Li (2006) [38] in grape, Wang *et al.* (2006) [39] in peach, Xu and Tian (2008) [41] in sweet cherry, Ding *et al.* (2007) [9] in mango, Huang *et al.* (2008) [12] in oranges, Xu and Tian (2008) [41] in sweet cherry, Kazemi *et al.* (2011) [17] in apple and Kranthi (2019) [35] in banana.

Total antioxidants (%DPPH activity)

The preharvest elicitors sprays significantly influenced the total antioxidants in papaya fruit pulp (Table-13). An increasing trend was observed with respect to total antioxidant capacity of the fruit pulp in treated fruits up to 9th day of storage and decline thereafter whereas in untreated fruits, the total antioxidant capacity was increased up to 6th day of storage and decreased later on. The preharvest elicitors Salicylic acid @ 300 ppm treatment (S_2) had recorded the highest total antioxidants (49.50% to 69.02% from 3rd to 9th day of storage respectively) which was on par with S_3 (Chitosan @ 1.5% (48.38% to 68.10% from 3rd to 9th day of storage respectively) and S_1 (Brassinosteroid @ 0.1%) treatments (47.91% to 66.69% from 3rd to 9th day of storage respectively). The lowest total antioxidant activity (45.68% to 59.63% from 3rd to 9th day of storage respectively) was recorded in unsprayed fruits (S_5). The total antioxidant activity was more in fruits harvested from the plants treated with preharvest elicitors Salicylic acid @ 300 ppm could be due to presence of more β-carotene (1.06 mg 100 g^{-1}), high ascorbic acid content (75.30 mg 100 g^{-1}), catalase (0.84 units/ mg protein/ min) and peroxidase (0.81 units/ mg protein/ min) enzyme activities in fruit pulp. Salicylic acid treatment might increase the total antioxidant activity by preventing the oxidation of phenolic compounds and promote the activation of alternative oxidase enzyme (AOX). Similar results were reported by Asghari (2006) [4] in strawberry; Qin *et al.* (2003) [26] in sweet cherry; Wei *et al.* (2011) [40] in asparagus and Hanif *et al.* (2020) [11] in papaya.

Shelf life (days)

The data on influence of preharvest elicitors sprays on shelf life of papaya var. Red Lady fruits was presented in Table-14. Significant differences were existed among the treatments for shelf life of fruits. The higher shelf life was found in fruits harvested from the plants treated with preharvest elicitors Salicylic acid @ 300 ppm S_2 (10.68 days), followed by Chitosan @ 1.5% S_3 treatment (9.96 days) as compared to the shelf life of fruits harvested from the plants without any elicitors spray (S_5) control (7.48 days) Salicylic acid was found effective in enhancing the shelf life of the fruits by 3 days as compared to control treatment. It could be due to reduction in loss of physiological weight (8.35%), delay in decrease of fruit firmness (9.90 kg cm^{-2}), less percentage of fruit spoilage (40.00%) maximum retention of TSS (11.40 °Brix) and more enzymatic (catalase (0.84 units/ mg protein/ min) and peroxidase (0.81 units/ mg protein/ min) and non-enzymatic antioxidants contents (β-carotene content (1.06 mg 100 g^{-1}) and ascorbic content (75.30 mg 100 g^{-1}) had extended the shelf life by 3 days in Salicylic acid treated fruits. It may also interfere with the 1-Aminocyclopropane-1-Carboxylic Acid (ACC) synthase and/or ACC oxidase activities which regulate the ethylene production (Raskin, 1992) [28] thereby increased the fruit shelf life as earlier reported by Mo *et al.* (2008) [23] in sugar apple; Shivendra and Singh (2015) [31] in mango cv. Dashehari; Devarkonda *et al.*, (2020) [7] and Kavya *et al.*, (2022a) [15] in papaya.

Table 1: Effect of pre harvest elicitors sprays on physiological loss in weight (%) of papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	5.02 (2.45*)	6.97 (2.82)	9.17 (3.16)	13.14
Salicylic acid @ 300 ppm (S_2)	4.27 (2.29)	6.37 (2.71)	8.35 (3.05)	11.67
Chitosan @ 1.5% (S_3)	4.60 (2.36)	6.65 (2.76)	8.75 (3.12)	12.70
Benzyl Adenine @ 50 ppm (S_4)	5.34 (2.52)	7.28 (2.88)	10.25 (3.21)	_
No spray (S_5)	6.28 (2.69)	8.33 (3.04)	12.99 (3.43)	_
S Em±	0.01	0.01	0.01	
CD at 5%	0.03	0.03	0.03	

* Figures in parenthesis are square root transformed values.

Table 2: Effect of pre harvest elicitors sprays on fruit firmness (Kg cm^{-2}) in papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	10.73	10.05	9.08	6.18
Salicylic acid @ 300 ppm (S_2)	11.69	10.95	9.90	6.73
Chitosan @ 1.5% (S_3)	11.22	10.49	9.46	6.51
Benzyl Adenine @ 50 ppm (S_4)	10.28	9.36	8.86	_
No spray (S_5)	9.20	7.68	7.50	_
S Em±	0.10	0.09	0.08	
CD at 5%	0.27	0.25	0.23	

Table 3: Effect of pre harvest elicitors sprays on fruit spoilage (%) in papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	2.22 (4.99*)	11.11 (11.75)	48.89 (44.40)	64.44 (53.71)
Salicylic acid @ 300 ppm (S_2)	0.00 (0.00)	6.67 (10.36)	40.00 (39.04)	51.11 (45.69)
Chitosan @ 1.5% (S_3)	0.00 (0.00)	8.89 (8.85)	46.67 (43.08)	60.00(51.15)
Benzyl Adenine @ 50 ppm (S_4)	6.67 (8.85)	20.00 (21.49)	57.78 (49.88)	75.56 (65.17)
No spray (S_5)	24.45 (29.24)	37.78 (36.30)	75.56 (61.85)	93.33 (81.15)
S Em±	0.07	0.19	0.36	0.32
CD at 5%	0.20	0.55	1.04	0.92

* Figures in parenthesis are angular transformation values.

Table 4: Effect of pre harvest elicitors sprays on titrable acidity (%) in papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	0.380 (1.18*)	0.291 (1.14)	0.243 (1.12)	0.203
Salicylic acid @ 300 ppm (S_2)	0.388 (1.18)	0.347 (1.16)	0.285 (1.13)	0.228
Chitosan @ 1.5% (S_3)	0.348 (1.16)	0.312 (1.15)	0.260 (1.12)	0.218
Benzyl Adenine @ 50 ppm (S_4)	0.331 (1.15)	0.296 (1.14)	0.221 (1.11)	_
No spray (S_5)	0.322 (1.15)	0.248 (1.12)	0.190 (1.09)	_
S Em±	0.001	0.001	0.001	
CD at 5%	0.004	0.004	0.003	

* Figures in parenthesis are square root transformed values.

Table 5: Effect of pre harvest elicitors sprays on Total Soluble Solids (°Brix) in papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	8.34	9.71	10.85	10.84
Salicylic acid @ 300 ppm (S_2)	8.87	10.10	11.40	11.72
Chitosan @ 1.5% (S_3)	8.71	9.83	11.12	10.98
Benzyl Adenine @ 50 ppm (S_4)	8.62	9.45	10.64	_
No spray (S_5)	8.56	10.36	10.20	_
S Em±	0.08	0.10	0.09	
CD at 5%	0.22	0.29	0.25	

Table 6: Effect of pre harvest elicitors sprays on total sugars (%) in papaya cv. Red Lady

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	6.99 (2.83*)	7.78 (2.96)	9.56 (3.25)	8.79
Salicylic acid @ 300 ppm (S_2)	7.55 (2.92)	8.14 (3.02)	9.89 (3.30)	9.63
Chitosan @ 1.5% (S_3)	7.25 (2.87)	7.96 (2.99)	9.66 (3.27)	9.14
Benzyl Adenine @ 50 ppm (S_4)	6.74 (2.78)	7.62 (2.94)	9.49 (3.24)	_
No spray (S_5)	7.01 (2.78)	8.21 (2.94)	8.76 (3.12)	_
S Em±	0.011	0.012	0.015	
CD at 5%	0.033	0.034	0.044	

* Figures in parenthesis are square root transformed values.

Table 7: Effect of pre harvest elicitors sprays on reducing sugars (%) in papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	4.41 (2.33*)	4.62 (2.37)	5.65 (2.58)	4.78
Salicylic acid @ 300 ppm (S_2)	4.66 (2.38)	4.84 (2.42)	5.94 (2.64)	5.81
Chitosan @ 1.5% (S_3)	4.52 (2.35)	4.71 (2.39)	5.73 (2.59)	5.21
Benzyl Adenine @ 50 ppm (S_4)	4.33 (2.31)	4.50 (2.35)	5.62 (2.57)	_
No spray (S_5)	4.35 (2.31)	4.96 (2.44)	5.10 (2.47)	_
S Em±	0.008	0.009	0.008	
CD at 5%	0.022	0.025	0.023	

* Figures in parenthesis are square root transformed values.

Table 8: Effect of pre harvest elicitors sprays on non-reducing sugars (%) in papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	2.44 (1.85*)	3.17 (2.04)	3.70 (2.17)	3.18
Salicylic acid @ 300 ppm (S_2)	2.72 (1.93)	3.28 (2.07)	3.90 (2.21)	3.78
Chitosan @ 1.5% (S_3)	2.62 (1.90)	3.21 (2.05)	3.83 (2.20)	3.19
Benzyl Adenine @ 50 ppm (S_4)	2.60 (1.90)	3.12 (2.03)	3.67 (2.16)	_
No spray (S_5)	2.32 (1.82)	3.24 (2.06)	3.50 (2.12)	_
S Em±	0.007	0.007	0.008	
CD at 5%	0.022	0.020	0.022	

* Figures in parenthesis are square root transformed values.

Table 9: Effect of pre harvest elicitors sprays on β-carotene content (mg 100 g^{-1}) in papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	0.63	0.88	1.09	1.18
Salicylic acid @ 300 ppm (S_2)	0.59	0.84	1.06	1.17
Chitosan @ 1.5% (S_3)	0.58	0.82	1.05	1.06
Benzyl Adenine @ 50 ppm (S_4)	0.69	0.96	1.11	_
No spray (S_5)	0.74	1.04	1.07	_
S Em±	0.006	0.008	0.010	
CD at 5%	0.017	0.023	0.028	

Table 10: Effect of pre harvest elicitors sprays on ascorbic acid (mg 100 g^{-1}) in papaya fruit cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	89.38	79.73	74.29	66.35
Salicylic acid @ 300 ppm (S_2)	91.50	81.24	75.30	68.35
Chitosan @ 1.5% (S_3)	90.40	80.38	74.76	66.95
Benzyl Adenine @ 50 ppm (S_4)	88.58	79.24	73.56	_
No spray (S_5)	84.59	75.64	70.31	_
S Em±	0.82	0.68	0.61	
CD at 5%	2.36	1.97	1.77	

Table 11: Effect of pre harvest elicitors sprays on catalase activity (units/mg protein /min) in papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	0.57	0.76	0.78	0.61
Salicylic acid @ 300 ppm (S_2)	0.38	0.68	0.84	0.71
Chitosan @ 1.5% (S_3)	0.47	0.72	0.80	0.65
Benzyl Adenine @ 50 ppm (S_4)	0.61	0.75	0.72	_
No spray (S_5)	0.64	0.82	0.68	___
S Em±	0.005	0.007	0.007	
CD at 5%	0.015	0.019	0.012	

Table 12: Effect of pre harvest elicitors sprays on peroxidase activity (units/mg protein/ min) of papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	0.40	0.74	0.75	0.62
Salicylic acid @ 300 ppm (S_2)	0.37	0.63	0.81	0.73
Chitosan @ 1.5% (S_3)	0.38	0.69	0.79	0.68
Benzyl Adenine @ 50 ppm (S_4)	0.39	0.79	0.73	_
No spray (S_5)	0.48	0.91	0.71	_
S Em±	0.004	0.005	0.006	
CD at 5%	0.011	0.016	0.019	

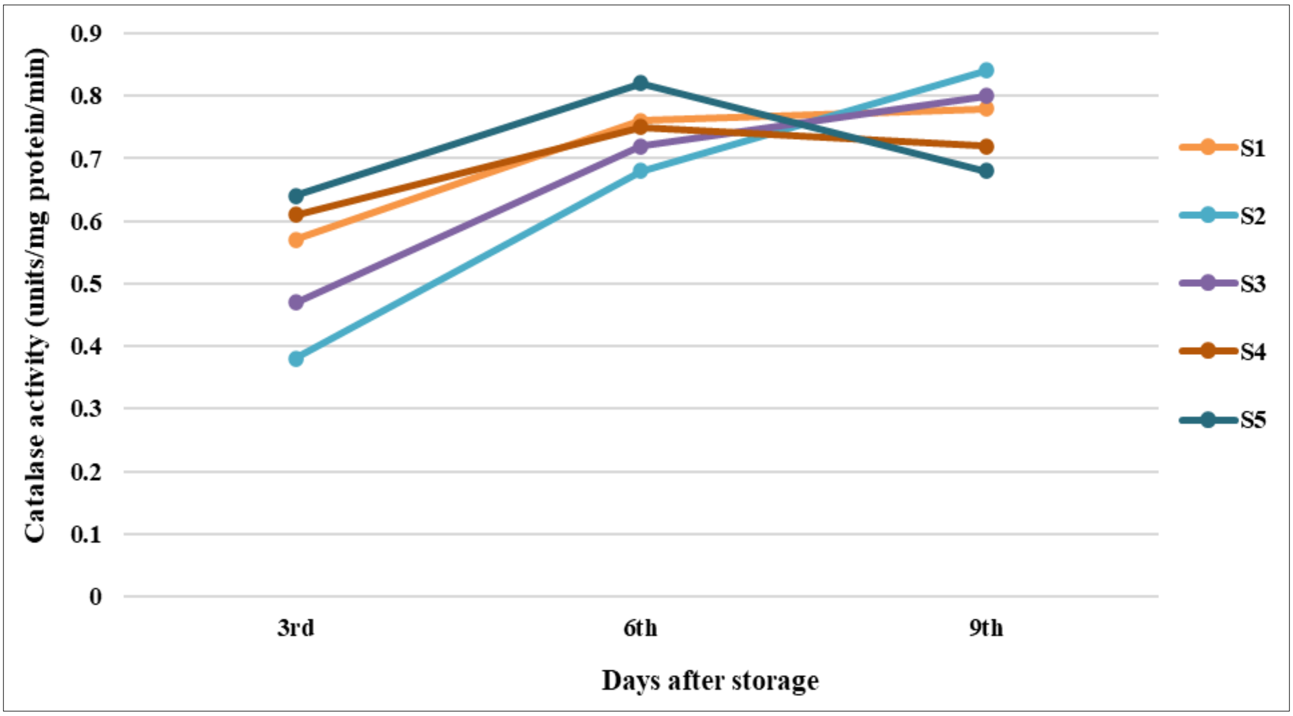
Table 13: Effect of pre harvest elicitors sprays on total antioxidants (% DPPH activity) in papaya cv. Red Lady.

Pre-harvest elicitors sprays	Day after storage			
	3rd	6th	9th	12th
Brassinosteroid @ 0.1% (S_1)	47.91 (43.78*)	56.88 (48.94)	66.69 (54.75)	55.93
Salicylic acid @ 300 ppm (S_2)	49.50 (44.70)	58.06 (49.62)	69.02 (56.18)	65.93
Chitosan @ 1.5% (S_3)	48.38 (44.05)	57.32 (49.19)	68.10 (55.61)	60.67
Benzyl Adenine @ 50 ppm (S_4)	47.01 (43.27)	55.79 (48.31)	65.06 (53.77)	_
No spray (S_5)	45.68 (42.50)	53.79 (45.58)	59.63 (50.62)	_
S Em±	0.24	0.26	0.36	
CD at 5%	0.70	0.75	1.03	

* Figures in parenthesis are angular transformation values.

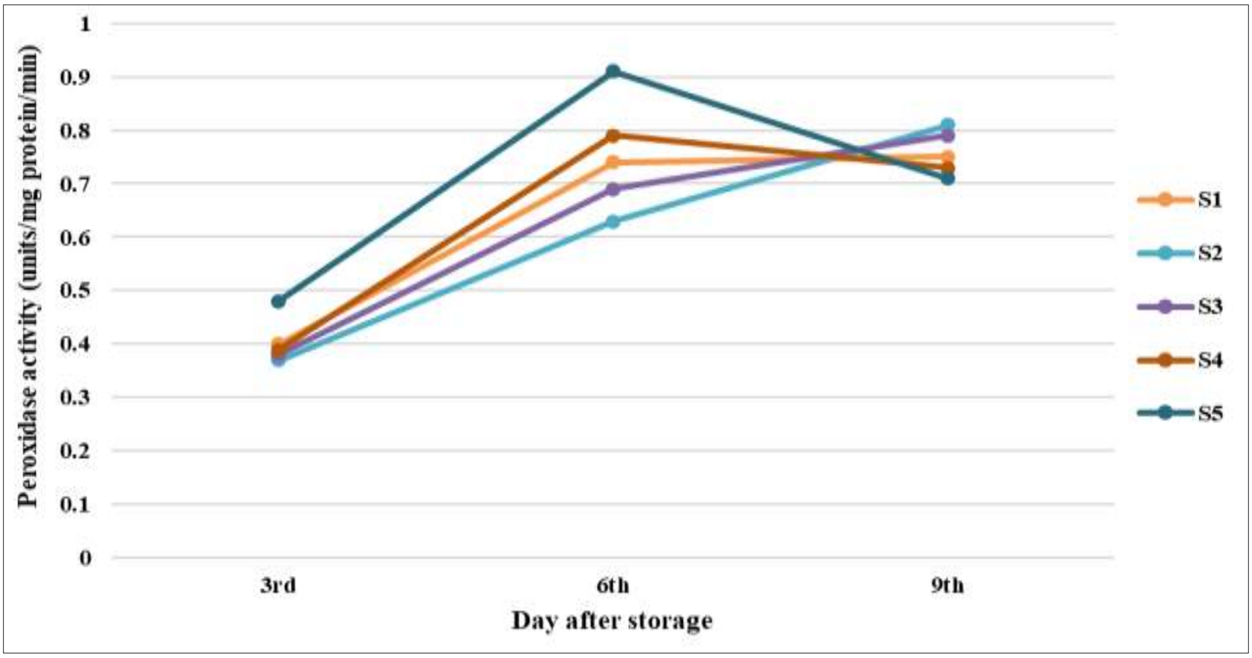
Table 14: Effect of pre harvest elicitors sprays on shelf life of fruit (days) in papaya cv. Red Lady.

Pre-harvest elicitors sprays	Days
Brassinosteroid @ 0.1% (S_1)	9.76
Salicylic acid @ 300 ppm (S_2)	10.68
Chitosan @ 1.5% (S_3)	9.96
Benzyl Adenine @ 50 ppm (S_4)	8.55
No spray (S_5)	7.48
S Em±	0.08
CD at 5%	0.24



S_1- Brassinosteroid @ 0.1%; S_2- Salicylic acid @ 300 ppm; S_3- Chitosan @ 1.5%;
S_4- Benzyl Adenine @ 50 ppm; S_5- No spray

Fig 1: Effect of pre harvest elicitors sprays on catalase activity (units/mg protein/min) in papaya cv. Red Lady.



S_1- Brassinosteroid @ 0.1%; S_2- Salicylic acid @ 300 ppm; S_3- Chitosan @ 1.5%;
S_4- Benzyl Adenine @ 50 ppm; S_5- No spray

Fig 2: Effect of pre harvest elicitors sprays on peroxidase activity (units/mg/min) of papaya cv. Red Lady

Conclusion

On the basis of results obtained in the present investigation, it could be concluded that, the fruits sprayed twice with Salicylic acid @ 300 ppm had performed best followed by Chitosan @ 1.5%, Brassinosteroid @ 0.1% and Benzyl Adenine @ 50 ppm with respect to both physical (PLW, fruit firmness, percent fruit spoilage and shelf life) and biochemical parameters *viz.*, TSS, titrable acidity, reducing sugars, ascorbic acid content and enzymatic antioxidants. The salicylic acid @ 300 ppm had showed no significant effect with other treatments with respect to total sugars, non-reducing sugars, β-carotene content and total antioxidant activities of the fruit pulp. Hence it could be concluded that elicitors as preharvest sprays were found more effective in maintaining the quality thereby extending the shelf life of fruits by 3 days. Further research work could be undertaken regarding physiological studies on preharvest application of elicitors, use of different concentration of elicitors to study its effect at different storage conditions and also use of pre harvest sprays of elicitors with other commercial varieties of papaya.

References

1. Anonymous. Crop wise area and production of Horticultural Crops. 2nd advance estimate (2021-2022), National Horticulture Board, Ministry of Agriculture and Farmer’s welfare, Govt. of India, New Delhi; c2022.
2. Ardakani E, Davarinejad GH, Azizi M. Impact of pre-harvest spray Salicylic acid application on storability, postharvest quality and antioxidant activity of apricot (*Prunus armeniaca* L.). Journal of Horticultural Science (Agricultural Sciences and Technology). 2013;26(4):448-459.
3. 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.
4. Asghari M. Effects of Salicylic acid on Selva strawberry fruit, antioxidant activity, ethylene production and senescence, fungal contamination and some other quality attributes. Ph.D. thesis. University of Tehran, Tehran, Iran; c2006.
5. Barrera E, Gil J, Restrepo A, Mosquera K, Durango D. A coating of Chitosan and propolis extract for the postharvest treatment of papaya (*Carica papaya* L. cv. Hawaiiana). National Agriculture. 2015;68(2):7667-78.
6. Candolle DA. Origin of cultivated plants. John Wiley and Sons, New York; c1884. p. 281.
7. Devarkonda S, Madhumathi C, Umamahesh V, Lakshmi LM, Reddy ML, Bhaskar VV, *et al*. Influence of pre-harvest spray of Salicylic acid and Jasmonic acid on fruit quality and postharvest behaviour of papaya (*Carica papaya* L.) cv. Red Lady. Journal of Pharmacognosy and Phytochemistry. 2020;9(3):622-26.
8. Ding CK, Wang CY. The dual effects of methyl salicylate on ripening and expression of ethylene biosynthetic genes in tomato fruit. Plant Science. 2003;164(4):589-596.
9. Ding ZS, Tian SP, Zheng XL, Zhou ZW, Xu Y. Responses of reactive oxygen metabolism and quality in mango fruit to exogenous oxalic acid or salicylic acid under chilling temperature stress. Physiologia Plantarum. 2007 May;130(1):112-121.
10. Eghdami A, Sadeghi F. Determination of total phenolic and flavonoids contents in methanolic and aqueous extract of *Achillea millefolium*. Organic Chemistry Journal. 2010;2:81-84.
11. Hanif A, Ahmad S, Shahzad S, Liaquat M, Anwar R. Postharvest 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.
12. Huang R, Xia R, Lu Y, Hu L, Xu Y. Effect of pre-harvest salicylic acid spray treatment on post-harvest antioxidant in the pulp and peel of ‘Cara cara’navel orange (*Citrus sinenisis* L. Osbeck). Journal of the Science of Food and Agriculture. 2008 Jan 30;88(2):229-236.

13. Jimenez A, Cressen G, Kular B, Firmin J, Robinson S, Verhoeyen M, *et al*. Changes in oxidative processes and components of the antioxidant system during tomato fruit ripening. Planta. 2002;214:751-758.
14. Karlidag H, Yildirim E, Turan M. Exogenous applications of salicylic acid affect quality and yield of strawberry grown under antifrost heated greenhouse conditions. Journal of Plant Nutrition and Soil Science. 2009 Apr;172(2):270-276.
15. Kavya K, Awati MG, Manjunath G, Venkatesh M, Ranjitha J, Jhalegar MJ. Role of pre-harvest application of elicitors and bio-formulations on physical, physiological quality and disease index of papaya (*Carica papaya* L.) var. Red Lady fruits during storage. The Pharma Innovation Journal. 2022a;11(3):448-455.
16. Kavya K, Awati MG, Manjunath G, Venkatesh M, Ranjitha J, Jhalegar MJ. Effect of pre-harvest application of elicitors and bio-formulations on biochemical characteristics and shelf life of papaya (*Carica papaya* L.) Fruits. The Pharma Innovation Journal. 2022b;11(3):456-59.
17. Kazemi M, Aran M, Zamani S. Effect of Salicylic acid treatments on quality characteristics of apple fruits during storage. American Journal of Plant Physiology. 2011;6(2):113-119.
18. Lane and Eyon, AOAC. Association of Official Agricultural Chemist, Official Methods of Analysis, AOAC, Washington DC; c1965.
19. Luck H. In: Methods in enzymatic analysis, 2nd edition Bergmeyer, Academic press, New York; c1974. p. 885.
20. Mallik CP, Singh MP. In: Plant enzymology and histoenzymology. Kalyani Publishers, New Delhi; c1980. p. 53.
21. Mapson CW. Vitamins in fruit: Stability of L-ascorbic acid. In: Biochemistry of fruits and their Products, Academic Press, London; c1970. p. 376-87.
22. Martínez-Esplá A, Serrano M, Valero D, Martínez-Romero D, Castillo S, Zapata PJ. Enhancement of antioxidant systems and storability of two plum cultivars by preharvest treatments with salicylates. International journal of molecular sciences. 2017;18(9):1911.
23. Mo Y, Gong D, Liang G, Han R, Xie J, Li W. Enhanced preservation effects of sugar apple fruits by Salicylic acid treatment during post-harvest storage. Journal of the Science of Food and Agriculture. 2008;88(15):2693-2699.
24. Orabi SA, Abd El-Motty EZ, El-Shamma MS, Abou-Hussein SD, Sharara FA. The effect of Salicylic acid and aspirin treatments on enzymes activity and fruit quality of clementine mandarin fruit during different cold storage periods. Middle East Journal Agricultural Research. 2018;7(2):583-593.
25. Prasad K, Paul JR. Post-harvest losses of papaya and practice for management. Food Sciences, 2021, 2(7).
26. Qin GZ, Tian SP, Xu Y, Wan YK. Enhancement of biocontrol efficacy of antagonistic yeasts by salicylic acid in sweet cherry fruit. Physiological and Molecular Plant Pathology. 2003 Mar 1;62(3):147-154.
27. Ranganna S. Handbook of analysis and quality control for fruits and vegetable products (second edition). Tata McGraw-Hill publishing company limited, New Delhi; c1986. p. 9-10.
28. Raskin I. Salicylate, a new plant hormone. Plant physiology. 1992 Jul;99(3):799.
29. Saini RS, Sharma KD, Dhankar OP, Kaushik RA. Laboratory manual of analytical techniques in horticulture. Agrobios (India); c2006.
30. Salari N, Bahraminejad A, Afsharmanesh G, Khajehpour G. Effect of Salicylic acid on post-harvest quantitative and qualitative traits of strawberry cultivars. Advances in Environmental Biology. 2012;7(1):94-99.
31. Shivendra K, Singh RP. Salicylic acid delayed ripening of mango fruits during storage in wooden crates. Green Farming. 2015;6(2):396-399.
32. Singh J, Tiwari JP. Effect of ethephon on the post-harvest quality of guava (*Psidium guajava* L) cv. Sardar Programme of Horticulture. 1994;26:189-93.
33. Singh VK, Saini JP, Misra AK. Response of Salicylic acid on flowering, floral malformation, fruit set, yield and associated biophysical and biochemical characters of mango. Indian Journal of Horticulture. 2001;58(3):196-201.
34. Srivastava MK, Dwivedi UN. Delayed ripening of banana fruit by Salicylic acid. Plant Science. 2000;158:87-96.
35. Kranthi Kumar T. Influence of ethylene inhibitors on shelf life and ethylene receptor gene expression in banana (*Musa paradisiaca* L.) cultivars. M.Sc. Thesis, Dr. Y.S.R. Horticultural University, Venkataramannagudem, West Godavari, Andhra Pradesh, India; c2019.
36. Venu MJ, Shruti Sethi, Sharma RR, Shalini GR. Impact of salicylic acid on the physiological and quality attributes of guava (*Psidium guajava*) fruits during storage at low temperature. Indian Journal of Agricultural Sciences. 2016;89(9):146-150.
37. Wang L, Li S. Role of salicylic acid in postharvest physiology. Fresh produce. 2008;2(1):1-5.
38. Wang L, Chen S, Kong W, Li S, Archbold DD. Salicylic acid pretreatment alleviates chilling injury and affects the antioxidant system and heat shock proteins of peaches during cold storage. Postharvest Biology and Technology. 2006 Sep 1;41(3):244-251.
39. Wang LJ, Li SH. Salicylic acid-induced heat or cold tolerance in relation to Ca2+ homeostasis and antioxidant systems in young grape plants. Plant Science. 2006 Apr 1;170(4):685-94.
40. Wei Y, Liu Z, Su Y, Liu D, Ye X. Effect of salicylic acid treatment on postharvest quality, antioxidant activities, and free polyamines of asparagus. Journal of food science. 2011 Mar;76(2):S126-S132.
41. Xu X, Tian S. Salicylic acid alleviated pathogen-induced oxidative stress in harvested sweet cherry fruit. Postharvest biology and technology. 2008 Sep 1;49(3):379-385.
42. Zhang Y, Zheng Q. Effect of polyamines and Salicylic acid on postharvest storage of ‘Ponkan’ mandarin. Acta Horticulturae. 2004;632:317-320.
43. Zhang Y, Chen K, Zhang S, Ferguson I. The role of salicylic acid in postharvest ripening of kiwifruit. Postharvest Biology and Technology. 2003 Apr 1;28(1):67-74.
44. Zhao J, Davis LC, Verpoorte R. Elicitor signal transduction leading to production of plant secondary metabolites. Biotechnology advances. 2005 Jun 1;23(4):283-333.
45. Zoran I, Avital BY, Yaccov P, Sharon AT, Elazar F. Total antioxidant activity of bell pepper during prolonged storage low temperature. Journal of Agriculture Sciences. 2008;53:1.