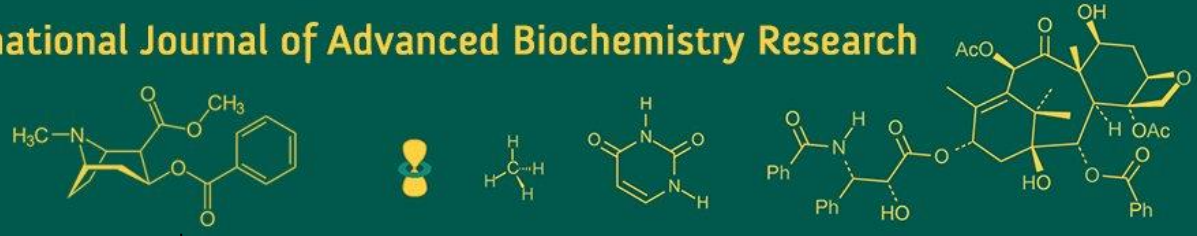
International Journal of Advanced Biochemistry Research



**ISSN Print:** 2617-4693
**ISSN Online:** 2617-4707
IJABR 2023; SP-7(2): 534-537
www.biochemjournal.com
Received: 01-09-2023
Accepted: 08-10-2023

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# Pre-harvest spray of plant elicitors at 50 and 70 days after anthesis improves postharvest quality of papaya (*Carica papaya* L.) cv. red lady

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**DOI:** https://doi.org/10.33545/26174693.2023.v7.i2Sg.262

**Abstract**
Plant elicitors were sprayed at pre-harvest stage mainly during anthesis of papaya to know the fruit quality and shelf life parameters. The trial was conducted during 2015-16 and 2016-17 at Horticultural Research station, Anantharajupeta, railway Kodur, Andhra Pradesh. In this salicylic acid was sprayed with different concentrations i.e. (50 ppm, 100 ppm, 150 ppm) and also jasmonic acid sprayed with different concentrations (50 µM, 100 µM, 150 µM) once during 50 Days After Anthesis and also twice (Two times) at 50 Days After Anthesis and also at 75 Days After Anthesis and control (no spray). Fruits were kept for storage in open condition. Titrable acidity showed a constant decline with enhancement of storage period upto 12 days. Whereas, lowest titrable acidity was observed in $T_{13}$ i.e. control upto 6$^{th}$ day of storage. By 9$^{th}$ day in the treatment $T_9$ (SA @ 150 ppm at 50 and 75 DAA) noticed the lowest titrable acidity (0.19%) which was on par with $T_8$ (0.18%) and $T_7$ (0.19%). As far as carotenoid content is concerned, an increasing trend with increase in storage life upto nine days of storage was observed and declined thereafter. With increasing storage period ascorbic acid content showed a declining trend. No significant difference was observed among treatments at 12 days after storage regarding ascorbic acid content.

**Keywords:** Shelf life, salicylic acid, jasmonic acid, elicitors, papaya

## Introduction
Papaya (*Carica papaya* L.) belongs to family Caricaceae rich in vitamin A and vitamin C (ascorbic acid) which helps in improving the body's immunity. In the world, papaya is cultivated in India, Brazil, Mexico and Indonesia and other countries in an area of 0.44 million ha with production of 13.89 million MT. Highest production of papaya in the world is from india occupies around 43.0 per cent of total world's papaya production. Papaya exports from India is 17930 MT mainly to countries like United Arab Emirates, Qutar, Saudi Arabia, Bahrain, Omen, US and Germany. For exporting to the distanct markets there is need to extend the storage life of papaya. There are some post-harvest quality problems in papaya mainly decay and excessive pulp firmness, uneven ripening, delicate nature of fruits which causes heavy spoilage and also weight loss and decay during transport. An elicitor can be naturally or synthetic compound that initiates induced plant defence against herbivores or pathogens. Jasmonic acid (JA) and Salicylic acid (SA) are signalling molecules helps in plant defence against many pathogens (Farousk and Osman, 2011) [3]. Salicylic acid (SA) is a plant phenolic phytohormone plays important role in plant growth, development and plant defence. Apart from that, both the elicitors i.e. SA and JA plays a major role in extending the shelf life and also in improving the fruit quality. The shelf-life extendes by salicylic acid through activity of inhibiting ethylene biosynthesis. SA blocks the conversion of 1-amino cyclo propane-1-carboxylic acid into ethylene (Leslie and Romain, 1986) [7]. Jasmonic Acid was also found effective in delaying the physiological loss of weight in plums. (Emine and Ozturk, 2014) [2].

**Materials and Methods:** The experiment was conducted at Horticultural Research Station, Anantharajupeta, Kadapa district, Andhra Pradesh. The experiment was laid out in a RBD

design with thirteen treatments and three replications. The treatments were Salicylic acid @ 50 ppm ($T_1$), 100 ppm ($T_2$), 150 ppm ($T_3$) sprayed once at 50DAA and Jasmonic acid @ 50 µ M ($T_4$), 100 µ M ($T_5$), 150 µ M ($T_6$) sprayed once at same period i.e. 50DAA, salicylic acid @ 50 ppm ($T_7$), 100 ppm ($T_8$), 150 ppm ($T_9$) sprayed twice at 50 DAA and also at 75 DAA, jasmonic acid @ 50 µ M ($T_{10}$), 100 µ M ($T_{11}$), 150 µ M ($T_{12}$) sprayed twice at same period i.e. 50 DAA and 75 DAA and no spray i.e. control ($T_{13}$). From tagged treated plants some of the full mature green papaya fruits were selected and harvested from each treatment separately. The collected fruits were graded into healthy marketable fruits, unmarketable fruits and disease fruits and only healthy fruits uses as experimental material. Fruits were harvested at colour break stage and kept for storage at ambient conditions. After harvesting of fruits observations were recorded on the physico-chemical characteristics for every 3 days.

## Results and Discussion

### Titrable acidity

Titrable acidity showed a constant decline with enhancement of storage period (Table 1). Lowest titrable acidity was observed in control upto 6th day of storage. By 9th day $T_9$ (SA @ 150 ppm at 50 and 75 DAA) noticed the lowest titrable acidity (0.19%) which was on a par with $T_8$ (0.18%) and also $T_7$ (0.19%).There is non-significant difference was seen among treatments regarding titrable acidity at 12 days after storage.

The content of titrable acidity declined progressively in papaya fruits harvested from both sprayed and control plants with the advancement of storage period. Similar reducing trend of titrable acidity kept at ambient temperatures was noted by Upadhyay *et al.*, (1994) [12] in mango. The decrease of titrable acidity might be due to when fruits attain maturity and ripening, acidity will be reduced as organic acids might be utilized as a substrate for respiration (Islam *et al.*, 2013) [14]. In our study titrable acidity during 3rd and 6th day of storage was minimum in control plants. Whereas during the 9th day of storage minimum titrable acidity was recorded in all the doses of salicylic acid applied twice. The treated fruits with salicylic acid exhibited low titrable acidity might be mainly due to reduction of senescence and delayed in ripening which leads to decrease of oxidation of acids.

**Table 1:** Effect of pre-harvest spray of salicylic acid and jasmonic acid on titrable acidity (%) in papaya

| Treatments | Days after harvest | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd | | | 6th | | | 9th | | | 12th | | |
| | I year 2015-16 | II year 2016-17 | Pooled data | I year 2015-16 | II year 2016-17 | Pooled data | I year 2015-16 | II year 2016-17 | Pooled data | I year 2015-16 | II year 2016-17 | Pooled data |
| $T_1$: Salicylic acid @ 50 ppm at 50 DAA | 0.35 | 0.35 | 0.35 | 0.31 | 0.33 | 0.32 | 0.26 | 0.25 | 0.26 | 0.22 | 0.22 | 0.22 |
| $T_2$: Salicylic acid @ 100 ppm at 50 DAA | 0.36 | 0.38 | 0.37 | 0.32 | 0.34 | 0.33 | 0.25 | 0.24 | 0.25 | 0.20 | 0.21 | 0.21 |
| $T_3$: Salicylic acid @ 150 ppm at 50 DAA | 0.39 | 0.42 | 0.41 | 0.32 | 0.34 | 0.33 | 0.26 | 0.26 | 0.26 | 0.21 | 0.21 | 0.21 |
| $T_4$: Jasmonic acid @ 50 µ M at 50 DAA | 0.38 | 0.41 | 0.40 | 0.29 | 0.33 | 0.31 | 0.22 | 0.23 | 0.23 | 0.19 | 0.21 | 0.20 |
| $T_5$: Jasmonic acid @ 100 µ M at 50 DAA | 0.39 | 0.41 | 0.40 | 0.34 | 0.35 | 0.35 | 0.26 | 0.27 | 0.27 | 0.21 | 0.22 | 0.22 |
| $T_6$: Jasmonic acid @ 150 µ M at 50 DAA | 0.42 | 0.40 | 0.41 | 0.33 | 0.33 | 0.33 | 0.25 | 0.26 | 0.26 | 0.20 | 0.20 | 0.20 |
| $T_7$: Salicylic acid @ 50 ppm at 50 DAA and 75 DAA | 0.36 | 0.36 | 0.36 | 0.29 | 0.29 | 0.29 | 0.20 | 0.21 | 0.21 | 0.19 | 0.19 | 0.19 |
| $T_8$: Salicylic acid @ 100 ppm at 50 DAA and 75 DAA | 0.32 | 0.35 | 0.34 | 0.27 | 0.28 | 0.28 | 0.20 | 0.22 | 0.21 | 0.18 | 0.18 | 0.18 |
| $T_9$: Salicylic acid @ 150 ppm at 50 DAA and 75 DAA | 0.32 | 0.35 | 0.34 | 0.25 | 0.28 | 0.27 | 0.19 | 0.19 | 0.19 | 0.18 | 0.19 | 0.19 |
| $T_{10}$: Jasmonic acid @ 50 µ M at 50 DAA and 75 DAA | 0.35 | 0.41 | 0.38 | 0.30 | 0.28 | 0.29 | 0.23 | 0.23 | 0.23 | 0.21 | 0.20 | 0.21 |
| $T_{11}$: Jasmonic acid @ 100 µ M at 50 DAA and 75 DAA | 0.36 | 0.40 | 0.38 | 0.30 | 0.30 | 0.30 | 0.23 | 0.25 | 0.24 | 0.19 | 0.21 | 0.20 |
| $T_{12}$: Jasmonic acid @ 150 µ M at 50 DAA and 75 DAA | 0.36 | 0.41 | 0.39 | 0.31 | 0.30 | 0.31 | 0.23 | 0.26 | 0.25 | 0.20 | 0.21 | 0.21 |
| $T_{13}$: Control | 0.27 | 0.30 | 0.28 | 0.21 | 0.23 | 0.22 | 0.27 | 0.27 | 0.27 | 0.23 | 0.24 | 0.23 |
| S.Em. ± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 |
| C.D. at 5% | 0.04 | 0.03 | 0.03 | 0.03 | 0.04 | 0.02 | 0.03 | 0.03 | 0.02 | NS | NS | NS |

DAA: Days after anthesis

### Carotenoid content

As far as carotenoid content is concerned, an increasing trend with increase in storage life upto nine days of storage was observed and declined there after (Table 2). On 9th day of storage $T_9$ recorded significantly high carotenoid content (1.93 mg $100g^{-1}$) which was statistically comparable with $T_8$ (1.87 mg $100g^{-1}$). Thus the carotenoid content was influenced by the pre-harvest application of salicylic acid (@ 100 and 150 ppm) and jasmonic acid (@100 µM and 150 µM) applied twice.

Papaya is rich in antioxidants and also carotenoids. The main carotenoids pigments in the red fleshed papaya are lycopene β-cryptoxanthin and β-carotene. In our study, content of carotenoid was influenced significantly by application of salicylic acid and jasmonic acid applied twice. Maximum betocarotene content (3037.1 mg/100 g) was reported by application of salicylic acid @ 0.5 g/lit in the variety "dashehari" at 20 days ambient storage period (Shivendra and Singh, 2015) [10]. It was observed in the present investigation that not only salicylic acid, but also jasmonic acid improved the carotene content when compared to control. Similar increase of carotenoids by application of methyl Jasmonate was also observed in grape fruit by Waseem *et al.* (2015) [13].

**Table 2:** Effect of pre-harvest spray of salicylic acid and jasmonic acid on total carotenoids content (mg $100\ g^{-1}$) in papaya

| Treatments | Days after harvest | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd | | | 6th | | | 9th | | | 12th | | |
| | I year 2015-16 | II year 2016-17 | Pooled data | I year 2015-16 | II year 2016-17 | Pooled data | I year 2015-16 | II year 2016-17 | Pooled data | I year 2015-16 | II year 2016-17 | Pooled data |
| $T_1$: Salicylic acid @ 50 ppm at 50 DAA | 1.42 | 1.36 | 1.39 | 1.47 | 1.45 | 1.46 | 1.57 | 1.56 | 1.57 | 1.53 | 1.42 | 1.48 |
| $T_2$: Salicylic acid @ 100 ppm at 50 DAA | 1.69 | 1.40 | 1.55 | 1.73 | 1.65 | 1.69 | 1.75 | 1.75 | 1.75 | 1.82 | 1.56 | 1.69 |
| $T_3$: Salicylic acid @ 150 ppm at 50 DAA | 1.50 | 1.43 | 1.47 | 1.55 | 1.56 | 1.55 | 1.72 | 1.67 | 1.70 | 1.63 | 1.52 | 1.58 |
| $T_4$: Jasmonic acid @ 50 µ M at 50 DAA | 1.29 | 1.27 | 1.28 | 1.35 | 1.39 | 1.37 | 1.51 | 1.54 | 1.53 | 1.47 | 1.40 | 1.44 |
| $T_5$: Jasmonic acid @ 100 µ M at 50 DAA | 1.51 | 1.43 | 1.47 | 1.58 | 1.55 | 1.57 | 1.67 | 1.70 | 1.68 | 1.71 | 1.65 | 1.68 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_6$: Jasmonic acid @ 150 µ M at 50 DAA | 1.42 | 1.34 | 1.38 | 1.47 | 1.51 | 1.49 | 1.59 | 1.58 | 1.59 | 1.57 | 1.45 | 1.51 |
| $T_7$: Salicylic acid @ 50 ppm at 50 DAA and 75 DAA | 1.59 | 1.51 | 1.55 | 1.75 | 1.63 | 1.69 | 1.76 | 1.66 | 1.71 | 1.70 | 1.65 | 1.68 |
| $T_8$: Salicylic acid @ 100 ppm at 50 DAA and 75 DAA | 1.66 | 1.53 | 1.59 | 1.84 | 1.64 | 1.74 | 1.90 | 1.85 | 1.87 | 1.82 | 1.75 | 1.78 |
| $T_9$: Salicylic acid @ 150 ppm at 50 DAA and 75 DAA | 1.72 | 1.61 | 1.67 | 1.83 | 1.76 | 1.79 | 1.95 | 1.91 | 1.93 | 1.92 | 1.83 | 1.88 |
| $T_{10}$: Jasmonic acid @ 50 µ M at 50 DAA and 75 DAA | 1.38 | 1.34 | 1.36 | 1.47 | 1.51 | 1.49 | 1.61 | 1.62 | 1.61 | 1.61 | 1.51 | 1.56 |
| $T_{11}$: Jasmonic acid @ 100 µ M at 50 DAA and 75 DAA | 1.53 | 1.44 | 1.48 | 1.65 | 1.61 | 1.63 | 1.65 | 1.71 | 1.68 | 1.73 | 1.69 | 1.71 |
| $T_{12}$: Jasmonic acid @ 150 µ M at 50 DAA and 75 DAA | 1.22 | 1.18 | 1.20 | 1.26 | 1.30 | 1.28 | 1.43 | 1.41 | 1.42 | 1.37 | 1.24 | 1.30 |
| $T_{13}$: Control | 1.17 | 1.15 | 1.16 | 1.21 | 1.22 | 1.22 | 1.36 | 1.33 | 1.34 | 1.32 | 1.20 | 1.26 |
| S.Em. ± | 0.06 | 0.05 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.03 | 0.02 | 0.21 | 0.26 | 0.17 |
| C.D. at 5% | 0.18 | 0.16 | 0.13 | 0.15 | 0.11 | 0.09 | 0.07 | 0.10 | 0.06 | NS | NS | NS |

DAA: Days after anthesis

**Ascorbic acid content**

Pre-harvest spray of plant elicitors on ascorbic acid content of the fruits kept at storage revealed a significant difference among the treatments from 3rd day to 9th day of storage (Table 3). No significant difference was observed among treatments at 12 days after storage. With increasing storage period, a declining trend was observed in ascorbic acid content. At 9th days after harvest in storage highest ascorbic acid content (71.22 mg 100 $g^{-1}$) was recorded in $T_9$ (SA @ 150 ppm sprayed at 50 and 75 DAA), which was comparable with $T_8$ (70.76 mg 100 $g^{-1}$). Whereas, the minimum content of ascorbic acid was observed with control (64.80 mg 100 $g^{-1}$). Thus, the present study revealed that spraying of salicylic acid twice (@ 100 ppm and 150 ppm) and also the application of jasmonic acid twice (@ 50 µM and @ 100 µM) showed a positive influence on content of ascorbic acid.

Ascorbic acid is the water soluble antioxidant present in the plants and protects plants fromoxidative damage. In our experiment, ascorbic acid content of fruits was declined gradually irrespective of the treatments with the advancement in period of storage. The content of ascorbic acid was enhanced by the application of salicylic acid @ 150 ppm and salicylic acid @ 100 ppm twice. The oxidation of L-ascorbic acid into dehydro ascorbic acid might be the major reason for decrease in content of ascorbic acid during storage (Mapson, 1970) [8].

Salicylic acid treatment increased the content of ascorbic acid might be due to increase levels in peroxidation of lipids considering that of fruit ripening is a oxidative phenomenon which requires turnover of active oxygen species (Jimenez *et al.*, 2002) [5]. The salicylic acid treatments leads to more retention of content of ascorbic acid might be due to delayed in the process of ripening caused by suppressed production of ethylene and also lower rate of respiration.

In present study, the ascorbic acid content was maximum in treatments of salicylic acid applied twice. But when compare to control Jasmonic acid @ 50 µM and 100 µM applied twice during 9th day storage also recorded higher content of ascorbic acid.

Similar improvement of ascorbic acid content with the application of jasmonic acid was reported by Emine and Ozturk (2014) [2] in the fortune plums, Ayala *et al.* (2005) [1] in strawberry. In strawberries ascorbic acid content was affected markedly by treatment with jasmonic acid. Wherein, more concentration of methyl jasmonate (60 µM) had the highest amount of ascorbic acid.

**Table 3:** Effect of pre-harvest spray of salicylic acid and jasmonic acid on ascorbic acid (mg 100 $g^{-1}$) in papaya

| Treatments | Days after harvest | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3rd | | | 6th | | | 9th | | | 12th | | |
| | I year 2015-16 | II year 2016-17 | Pooled data | I year 2015-16 | II year 2016-17 | Pooled data | I year 2015-16 | II year 2016-17 | Pooled data | I year 2015-16 | II year 2016-17 | Pooled data |
| $T_1$: Salicylic acid @ 50 ppm at 50 DAA | 81.47 | 82.58 | 82.03 | 73.25 | 73.50 | 73.37 | 68.43 | 64.52 | 66.48 | 64.50 | 63.50 | 64.00 |
| $T_2$: Salicylic acid @ 100 ppm at 50 DAA | 81.55 | 80.69 | 81.12 | 71.81 | 70.93 | 71.37 | 67.83 | 66.05 | 66.94 | 64.01 | 62.01 | 63.01 |
| $T_3$: Salicylic acid @ 150 ppm at 50 DAA | 82.52 | 82.16 | 82.34 | 76.05 | 73.41 | 74.73 | 67.69 | 65.21 | 66.45 | 64.20 | 62.80 | 63.50 |
| $T_4$: Jasmonic acid @ 50 µ M at 50 DAA | 81.68 | 78.49 | 80.08 | 77.25 | 74.80 | 76.03 | 66.32 | 67.05 | 66.68 | 66.81 | 63.46 | 65.14 |
| $T_5$: Jasmonic acid @ 100 µ M at 50 DAA | 80.56 | 80.24 | 80.40 | 72.92 | 71.80 | 72.36 | 67.91 | 65.42 | 66.66 | 62.34 | 59.02 | 60.68 |
| $T_6$: Jasmonic acid @ 150 µ M at 50 DAA | 79.52 | 79.10 | 79.31 | 74.37 | 72.68 | 73.53 | 67.32 | 65.08 | 66.20 | 63.50 | 61.27 | 62.39 |
| $T_7$: Salicylic acid @ 50 ppm at 50 DAA and 75 DAA | 83.56 | 83.52 | 83.54 | 78.31 | 75.61 | 76.96 | 68.75 | 68.51 | 68.63 | 64.68 | 63.48 | 64.08 |
| $T_8$: Salicylic acid @ 100 ppm at 50 DAA and 75 DAA | 84.35 | 85.11 | 84.73 | 79.07 | 77.27 | 78.17 | 70.73 | 70.78 | 70.76 | 66.21 | 62.51 | 64.36 |
| $T_9$: Salicylic acid @ 150 ppm at 50 DAA and 75 DAA | 85.62 | 84.72 | 85.17 | 81.57 | 78.56 | 80.07 | 72.04 | 70.39 | 71.22 | 67.34 | 65.21 | 66.27 |
| $T_{10}$: Jasmonic acid @ 50 µ M at 50 DAA and 75 DAA | 81.33 | 76.38 | 78.86 | 78.86 | 75.03 | 76.94 | 67.16 | 67.32 | 67.24 | 63.92 | 62.54 | 63.23 |
| $T_{11}$: Jasmonic acid @ 100 µ M at 50 DAA and 75 DAA | 82.03 | 77.88 | 79.96 | 74.39 | 72.40 | 73.39 | 68.53 | 66.86 | 67.69 | 62.53 | 63.60 | 63.07 |
| $T_{12}$: Jasmonic acid @ 150 µ M at 50 DAA and 75 DAA | 82.16 | 78.21 | 80.18 | 76.60 | 71.91 | 74.26 | 67.97 | 65.60 | 66.78 | 62.19 | 62.86 | 62.53 |
| $T_{13}$: Control | 78.16 | 75.41 | 76.79 | 70.50 | 70.69 | 70.59 | 65.64 | 63.95 | 64.80 | 63.50 | 63.05 | 63.28 |
| S.Em. ± | 1.09 | 1.07 | 0.87 | 1.16 | 1.02 | 0.92 | 1.01 | 1.10 | 0.74 | 1.17 | 2.18 | 1.20 |
| C.D. at 5% | 3.18 | 3.12 | 2.53 | 3.38 | 2.98 | 2.69 | 2.94 | 3.21 | 2.17 | NS | NS | NS |

DAA: Days after anthesis

**Conclusion**

Salicylic acid with 150 ppm sprayed twice at 50 Days after Anthesis and also at 75 Days After Anthesis ($T_9$) decreased the level of titrable acidity and ascorbic acid content during storage period, whereas increased the carotenoid content upto nine days of storage later showed a declining trend.

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