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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

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Abstract
To study the effect of preharvest spray of plant elicitors at flowering on shelf life and fruit quality parameters of papaya, was planned at Horticultural Research station, anantharajupeta, railway kodur, Andhra Pradesh during 2015-16 and 2016-17 with the application of different concentrations of salicylic acid (50 ppm, 100 ppm, 150 ppm), jasmonic acid (50 µM, 100 µM, 150 µM) once at 50 Days After Anthesis and twice at 50 Days After Anthesis and 75 Days After Anthesis and control (no spray). Among various treatments, foliar spray of salicylic acid (150 ppm) at 50 and 75 DAA (T_9) recorded the lowest physiological loss in weight (11.89%) of fruits which stood at par with T_8 (12.05%) even at 12 days after storage. The positive influence of T_9 and T_8 was also observed in extending the shelf life of papaya fruits over control during storage. The quality attributes such as total sugars, reducing sugars, non reducing sugars, and sugar-acid ratio showed an increasing trend up to 9 days after storage and decreased further.

Keywords: Papaya, physiological loss in weight, salicylic acid, total sugars

Introduction
Papaya (*Carica papaya* L.) belongs to the genus *Carica*, of the family Caricaceae. Papaya is cultivated in the world in an area of 0.44 million ha with production of 12.67 million MT. Almost 44.4 per cent of world's papaya production is from India. From India 12,773 MT of papaya exporting to different countries specially United Arab Emirates, Saudi Arabia, Netherland, Bahrain, Qutar, Omen, Nepal, US and Germany (Indiastat, 2016-17). Extending the shelf life period of papaya is need of the day as it is transported to very distant markets. Jasmonic acid (JA) and Salicylic acid (SA) are two endogenous signalling molecules used in regulation of plant defence to pathogens by systemic acquired resistance (Farousk and Osman, 2011) [6]. SA is considered as a hormone-like substance and plays an important role in the regulation of plant growth and development. Further, it was reported that SA and JA plays an important role in extending the shelf life and improving post-harvest quality of the fruit. Salicylic acid inhibits ethylene biosynthesis in plants by blocking the conversion of 1-amino cyclo propane-1-carboxylic acid to ethylene (Leslie and Romain, 1986) [11]. The shelf life of straw berry fruits was extended upto 11 days with methyl jasmonate compared with control (6 days) and also maintained the initial TSS values. (Ayala *et al*., 2005) [2]. Methyl jasmonate was also found effective in delaying the weight loss of black beauty of plums. (Emine and Ozturk, 2014) [5]. Hence, SA and JA were used as preharvest spray to extend the shelflife of papaya. Physiologically papaya is a climacteric fruit with typical respiratory peak and ethylene production patterns during ripening. Among several post-harvest quality problems in papaya, pulp firmness, decay of the fruit and excessive pulp rotting at the edible stage are some crucial parameters to be taken care of. It is also true that the extremely delicate nature of papaya fruits causes more weight loss and heavy spoilage during transport before it reaches to the consumer.

Materials and Methods
The experiment was carried out the from November, 2015 to October, 2016 and November, 2016 to October, 2017 at Horticultural Research Station, Anantharajupeta, Kadapa district, Andhra Pradesh, which is situated at an altitude of 162 meters (531 feet) above mean sea level and at 13.99° North latitude and 79.30° East longitude which falls under tropical zone with a normal rainfall of 966.1 mm.

The experiment was laid out in a randomized block design with thirteen treatments and three replications. The treatments tested were application of salicylic acid @ 50 ppm (T_1), 100 ppm (T_2), 150 ppm (T_3) at 50DAA, jasmonic acid @ 50 µ M (T_4), 100 µ M (T_5), 150 µ M (T_6) at 50DAA, salicylic acid @ 50 ppm (T_7), 100 ppm (T_8), 150 ppm (T_9) at 50 DAA and 75 DAA, jasmonic acid @ 50 µ M (T_{10}), 100 µ M (T_{11}), 150 µ M (T_{12}) at 50 DAA and 75 DAA and control (T_{13}). Fruits were harvested from tagged plants which were sprayed with different concentration of salicylic acid and jasmonic acid at 50 and 75 DAA based on treatments. This experiment was carried out by collecting full mature green papaya fruits from each treatment separately. The total fruits were separated into healthy marketable fruits, disease fruits and unmarketable fruits. Experimental fruit material was selected randomly from the lot of healthy marketable fruits. Fruits were harvested at colour break stage when green colour changed to light green with slight yellowish tinge at blossom end. Observations on the physico-chemical characteristics were recorded for every 3 days after harvesting of fruits. These fruits were kept for storage at ambient temperatures.

Results and Discussion

The results from this experiment showed that application of salicylic acid and jasmonic acid at 50 and 75 days after anthesis (approximately 170 and 185 days after transplanting) significantly influenced the physiological loss in weight per cent (Table 1). Application of salicylic acid @ 150 ppm at 50 and 75 DAA (T_9) recorded lowest physiological loss in weight (11.89%) of fruits which stood at a par with T_8 (SA @ 100 ppm at 50 and 75 DAA) (12.02%) and T_7 (SA @ 50 ppm at 50 and 75 DAA) (12.05%) even after 12 days after storage. Whereas highest physiological loss in weight (15.58, 16.24 and 15.91%) was recorded with the fruits obtained from untreated plants (T_{13}) during both years of study as well as in pooled mean.

Further, jasmonic acid @ 150 µM also recorded reduced physiological loss in weight and it was found at par with salicylic acid during 9th and 12th day of observation.

The positive result of application of T_9 (SA @ 150 ppm at 50 and 75 DAA) and T_8 (SA @ 100 ppm at 50 and 75 DAA) was also observed on increased shelf life in days(Table 2). The data recorded in both years and in its pooled mean revealed that highest shelf life of papaya fruits (10.33 days, 10.67 days and 10.50 days) was recorded in treatment T_9 (SA @ 150 ppm at 50 and 75 DAA) which was at a par with T_8 (SA @ 100 ppm at 50 and 75 DAA) (10.00 days, 10.33 days and 10.17 days). However, the fruits obtained from untreated plants i.e., T_{13} (control) recorded minimum shelf life (6.00 days, 6.33 days and 6.17 days).

The study indicated significantly better efficacy by application of salicylic acid at two different stages *viz.,* 50 and 75 DAA than application in single stage (50 DAA) of crop growth, which might be due to the efficacy of salicylic acid at higher rate (SA 150 ppm at 50 and 75 DAA; SA @ 100 ppm at 50 and 75 DAA) than lower rate of application.

Higher PLW in fruits harvested from untreated plants during storage might be due to their active metabolism such as respiration and transpiration in turn led to heavy loss of water resulting in visually shrivelling of papaya. Apart from that, in untreated plants due to higher pectin metylesterase activity leads to rapid ripening in fruits during which the cell wall polymers such as cellulose, pectin and hemicellulose undergo substantial transformation and solubilisation resulting in degradation of cell wall and softening of fruit also might caused PLW in fruits (Yashoda, 2003) [20].

Both the plant elicitors are effective in improving the shelf life of papaya fruits when sprayed at 50 and 75 days after anthesis when compared to control.

The increase in shelf life due to salicylic acid application might be attributed due to SA increases fruit firmness (Srivastava and Dwivedi, 2000) [18] by decreasing the activity of cell wall degrading enzyme like pectinmethyl esterase, cellulase, polygalactronase, xylanse, and β-1-3 glucanase (Ali *et al,* 2004), ability of salicylic acid to induce Systemic Acquired Resistance (SAR) providing protection against pathogen attack and other stresses (Hayat *et al.,* 2007) and also delayed production of ethylene (Raskin, 1992). Such suppression of ethylene production might be associated with the decreased 1-Aminocyclopropane-1– Carboxylic Acid (ACC) synthase and or ACC oxidase activity as reported in Banana. (Srivastava and Dwivedi, 2000) [18].

The study indicated significantly better efficacy by application of salicylic acid at two different stages *viz.,* 50 and 75 DAA than application in single stage (50 DAA) of crop growth, which might be due to efficacy of salicylic acid at higher rate than lower rate of application. Similar report of better efficacy of salicylic acid at higher frequency of spray than lower frequency of spray was reported by Bideshki and Arvin (2010) [3] in garlic.

The role of jasmonic acid enhancing the shelf life in papaya fruits might be due to increased of fruit firmness, reduced lipid peroxidation and reduction of PLW. Besides the other important reason is the induction and synthesis of some stress proteins such as heat shock proteins and pathogen related proteins that decrease the incidence of decay by increased resistance to pathogens (Ding *et al.,* 2001) [4]. Similar effect of jasmonic acid in extending the shelf life of strawberry fruits by suppression of fungal decay with induced defence mechanism was reported by Ayala *et al.* (2005) [2].

Pre-harvest spray of plant elicitors also influenced the biochemical parameters of fruits during post harvest storage.

A gradual increase in total sugars during the storage period was observed in all the treatments upto 9th day of storage it was decreased later on (Table 3). However, in control (T_{13}) higher Total sugars was recorded at 6 days after storage and showed a declining trend later on. At 9 days after storage highest total sugars content was recorded with T_9 (10.21%) which was at par with T_8 (9.95%) and the lowest value was observed with T_{13} (8.54). A similar trend was also observed with reducing sugars (%), non reducing sugars (%) and sugar acid ratio (Table 4, 5 and 6). At the same period reducing sugars were highest with T_7 (6.13%) which was at par with T_9 (6.07%) and T_8 (6.04%). Whereas, T_{13} recorded the lowest content of reducing sugars (5.15%). Further, the highest content of non reducing sugars was also seen with T_9 (SA 150 ppm at 50 and 75 DAA) and the lowest of this was seen in T_{13} (control) (2.68%). This could be due to the faster ripening process in control which was regulated by the application of salicylic acid and jasmonic acid.

Sugar acid ratio was highest (41.45) in control at 6th day after storage which was declined thereafter (Table 6). Whereas, application of salicylic acid @ 150 ppm at 50 and 75 DAA (T_9) recorded highest sugar acid ratio (53.92) at 9 days after storage and the same was declined thereafter. It was observed that by 12th day after storage T_8 recorded highest sugar acid ratio (46.22) which was at par with T_9 (44.89) and T_7 (42.71) while the lowest (28.92) was seen with control.

Table 1: Effect of pre-harvest spray of salicylic acid and jasmonic acid on physiological loss in weight (%) 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	3.80	4.05	3.92	7.91	7.72	7.82	10.11	10.23	10.17	12.39	12.43	12.41
T_2: Salicylic acid @ 100 ppm at 50 DAA	3.77	3.98	3.88	8.02	7.53	7.77	10.64	10.35	10.50	12.32	12.43	12.38
T_3: Salicylic acid @ 150 ppm at 50 DAA	3.50	3.63	3.57	7.32	7.46	7.39	11.38	10.54	10.96	13.10	12.14	12.62
T_4: Jasmonic acid @ 50 µ M at 50 DAA	4.36	4.19	4.28	8.72	8.90	8.81	11.99	12.42	12.20	13.75	13.97	13.86
T_5: Jasmonic acid @ 100 µ M at 50 DAA	3.98	4.39	4.18	7.34	8.32	7.83	10.56	10.90	10.73	12.47	12.54	12.50
T_6: Jasmonic acid @ 150 µ M at 50 DAA	3.83	4.14	3.99	7.67	7.78	7.72	11.14	11.06	11.10	12.85	12.78	12.81
T_7: Salicylic acid @ 50 ppm at 50 DAA and 75 DAA	3.46	3.68	3.57	7.05	6.90	6.97	9.97	10.01	9.99	12.09	12.01	12.05
T_8: Salicylic acid @ 100 ppm at 50 DAA and 75 DAA	3.53	3.64	3.59	6.83	7.00	6.91	10.07	9.94	10.01	12.13	11.90	12.02
T_9: Salicylic acid @ 150 ppm at 50 DAA and 75 DAA	3.44	3.61	3.52	6.78	6.86	6.82	9.87	9.97	9.92	11.96	11.81	11.89
T_{10}: Jasmonic acid @ 50 µ M at 50 DAA and 75 DAA	4.76	4.19	4.48	10.48	8.83	9.65	12.71	11.72	12.21	14.52	13.48	14.00
T_{11}: Jasmonic acid @ 100 µ M at 50 DAA and 75 DAA	3.78	4.04	3.91	7.51	7.33	7.42	11.45	10.82	11.14	13.18	12.60	12.89
T_{12}: Jasmonic acid @ 150 µ M at 50 DAA and 75 DAA	3.77	4.01	3.89	7.53	7.68	7.61	10.10	10.23	10.16	12.21	12.25	12.23
T_{13}: Control	5.61	5.73	5.67	9.42	9.83	9.63	13.71	14.35	14.03	15.58	16.24	15.91
S.Em. ±	0.07	0.11	0.08	0.09	0.11	0.07	0.12	0.11	0.08	0.10	0.18	0.09
C.D. at 5%	0.21	0.33	0.22	0.28	0.33	0.22	0.34	0.32	0.24	0.29	0.52	0.27

DAA: Days after anthesis

Table 2: Effect of pre-harvest spray of salicylic acid and jasmonic acid on shelf life (Days) in papaya

Treatments	I year 2015-16	II year 2016-17	Pooled data
T_1: Salicylic acid @ 50 ppm at 50 DAA	8.33	8.00	8.17
T_2: Salicylic acid @ 100 ppm at 50 DAA	8.00	8.00	8.00
T_3: Salicylic acid @ 150 ppm at 50 DAA	8.67	8.67	8.67
T_4: Jasmonic acid @ 50 µ M at 50 DAA	7.00	7.33	7.17
T_5: Jasmonic acid @ 100 µ M at 50 DAA	7.33	7.67	7.50
T_6: Jasmonic acid @ 150 µ M at 50 DAA	7.67	7.67	7.67
T_7: Salicylic acid @ 50 ppm at 50 DAA and 75 DAA	9.00	9.33	9.17
T_8: Salicylic acid @ 100 ppm at 50 DAA and 75 DAA	10.00	10.33	10.17
T_9: Salicylic acid @ 150 ppm at 50 DAA and 75 DAA	10.33	10.67	10.50
T_{10}: Jasmonic acid @ 50 µ M at 50 DAA and 75 DAA	8.33	8.33	8.33
T_{11}: Jasmonic acid @ 100 µ M at 50 DAA and 75 DAA	8.67	9.00	8.83
T_{12}: Jasmonic acid @ 150 µ M at 50 DAA and 75 DAA	9.33	9.33	9.33
T_{13}: Control	6.00	6.33	6.17
S.Em. ±	0.27	0.35	0.24
C.D. at 5%	0.79	1.01	0.70

DAA: Days after anthesis

Table 3: Effect of pre-harvest spray of salicylic acid and jasmonic acid on total sugars (%) 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	7.25	7.03	7.14	8.04	7.47	7.76	9.67	9.36	9.51	7.19	7.46	7.32
T_2: Salicylic acid @ 100 ppm at 50 DAA	6.76	6.82	6.79	8.07	7.05	7.56	9.78	9.13	9.46	7.27	7.91	7.59
T_3: Salicylic acid @ 150 ppm at 50 DAA	6.60	6.52	6.56	8.01	7.86	7.94	9.29	8.65	8.97	7.70	6.75	7.23
T_4: Jasmonic acid @ 50 µ M at 50 DAA	6.29	6.46	6.37	8.07	7.90	7.99	9.50	8.95	9.22	7.70	7.63	7.66
T_5: Jasmonic acid @ 100 µ M at 50 DAA	6.86	6.49	6.68	7.55	7.53	7.54	9.04	9.08	9.06	7.35	7.03	7.19
T_6: Jasmonic acid @ 150 µ M at 50 DAA	6.74	6.56	6.65	7.99	7.74	7.86	9.76	9.62	9.69	7.80	7.64	7.72
T_7: Salicylic acid @ 50 ppm at 50 DAA and 75 DAA	7.26	7.01	7.14	8.35	8.21	8.28	10.12	9.70	9.91	8.24	7.91	8.08
T_8: Salicylic acid @ 100 ppm at 50 DAA and 75 DAA	7.54	7.15	7.34	8.43	8.32	8.38	9.89	10.01	9.95	8.30	8.13	8.21
T_9: Salicylic acid @ 150 ppm at 50 DAA and 75 DAA	7.57	6.60	7.08	8.45	8.34	8.40	10.26	10.16	10.21	8.36	8.16	8.26
T_{10}: Jasmonic acid @ 50 µ M at 50 DAA and 75 DAA	6.95	6.78	6.87	8.35	8.03	8.19	9.74	9.54	9.64	7.91	7.43	7.67
T_{11}: Jasmonic acid @ 100 µ M at 50 DAA and 75 DAA	6.76	6.90	6.83	7.66	8.15	7.91	9.67	9.16	9.41	7.81	7.04	7.42
T_{12}: Jasmonic acid @ 150 µ M at 50 DAA and 75 DAA	6.60	6.62	6.61	8.41	8.03	8.22	9.70	9.18	9.44	7.59	7.87	7.73
T_{13}: Control	8.57	8.32	8.44	9.21	9.14	9.17	8.51	8.57	8.54	6.95	6.47	6.71
S.Em. ±	0.14	0.18	0.11	0.16	0.07	0.08	0.14	0.12	0.10	0.17	0.16	0.12
C.D. at 5%	0.41	0.51	0.32	0.45	0.21	0.23	0.41	0.34	0.29	0.49	0.46	0.34

DAA: Days after anthesis

Table 4: Effect of pre-harvest spray of salicylic acid and jasmonic acid on reducing sugars (%) 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	4.50	4.09	4.30	4.83	4.64	4.74	5.98	5.67	5.83	4.17	4.49	4.33
T_2: Salicylic acid @ 100 ppm at 50 DAA	3.89	3.95	3.92	4.87	4.05	4.46	5.77	5.25	5.51	4.19	4.51	4.35
T_3: Salicylic acid @ 150 ppm at 50 DAA	3.91	4.02	3.97	4.79	4.66	4.72	5.53	5.12	5.33	4.78	4.04	4.41
T_4: Jasmonic acid @ 50 µ M at 50 DAA	3.76	3.71	3.74	4.87	5.07	4.97	5.72	5.39	5.56	4.76	4.51	4.64
T_5: Jasmonic acid @ 100 µ M at 50 DAA	3.97	3.85	3.91	4.37	4.62	4.49	5.49	5.17	5.33	4.35	4.05	4.20
T_6: Jasmonic acid @ 150 µ M at 50 DAA	3.96	4.11	4.03	4.69	4.55	4.62	5.73	5.69	5.71	4.75	4.52	4.63
T_7: Salicylic acid @ 50 ppm at 50 DAA and 75 DAA	4.55	4.39	4.47	4.82	5.13	4.97	6.25	6.01	6.13	5.10	4.76	4.93
T_8: Salicylic acid @ 100 ppm at 50 DAA and 75 DAA	4.54	4.31	4.43	4.78	5.17	4.98	6.01	6.06	6.04	5.02	4.72	4.87
T_9: Salicylic acid @ 150 ppm at 50 DAA and 75 DAA	4.52	3.30	3.91	4.79	5.19	4.99	6.11	6.03	6.07	5.04	4.69	4.86
T_{10}: Jasmonic acid @ 50 µ M at 50 DAA and 75 DAA	4.04	4.17	4.11	4.85	4.95	4.90	5.83	5.62	5.73	4.89	4.36	4.62
T_{11}: Jasmonic acid @ 100 µ M at 50 DAA and 75 DAA	4.33	4.22	4.28	4.58	4.98	4.78	5.84	5.44	5.64	4.60	4.44	4.52
T_{12}: Jasmonic acid @ 150 µ M at 50 DAA and 75 DAA	4.19	3.83	4.01	4.75	5.10	4.93	5.88	5.53	5.70	4.38	4.46	4.42
T_{13}: Control	5.14	5.08	5.11	5.26	5.58	5.42	5.09	5.21	5.15	4.14	3.92	4.03
S.Em. ±	0.17	0.11	0.11	0.09	0.08	0.07	0.09	0.11	0.08	0.48	0.50	0.45
C.D. at 5%	0.51	0.31	0.32	0.27	0.24	0.21	0.27	0.33	0.25	NS	NS	NS

DAA: Days after anthesis

Table 5: Effect of pre-harvest spray of salicylic acid and jasmonic acid on non reducing sugars (%) 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	2.74	2.94	2.84	3.21	2.83	3.02	3.69	3.54	3.61	3.02	2.97	2.99
T_2: Salicylic acid @ 100 ppm at 50 DAA	2.87	2.88	2.88	3.21	3.00	3.10	4.01	3.88	3.95	3.08	3.41	3.24
T_3: Salicylic acid @ 150 ppm at 50 DAA	2.69	2.50	2.59	3.22	3.20	3.21	3.76	3.52	3.64	2.92	2.71	2.82
T_4: Jasmonic acid @ 50 µ M at 50 DAA	2.53	2.75	2.64	3.20	2.83	3.02	3.78	3.56	3.67	2.94	3.11	3.03
T_5: Jasmonic acid @ 100 µ M at 50 DAA	2.89	2.65	2.77	3.18	2.91	3.05	3.55	3.91	3.73	2.99	2.98	2.99
T_6: Jasmonic acid @ 150 µ M at 50 DAA	2.78	2.45	2.62	3.30	3.20	3.25	4.03	3.93	3.98	3.05	3.12	3.09
T_7: Salicylic acid @ 50 ppm at 50 DAA and 75 DAA	2.71	2.62	2.67	3.53	3.09	3.31	3.87	3.63	3.75	3.14	3.15	3.15
T_8: Salicylic acid @ 100 ppm at 50 DAA and 75 DAA	2.99	2.84	2.92	3.65	3.15	3.40	3.88	3.98	3.93	3.29	3.41	3.35
T_9: Salicylic acid @ 150 ppm at 50 DAA and 75 DAA	3.05	2.85	2.95	3.66	3.15	3.41	4.15	4.09	4.12	3.32	3.47	3.40
T_{10}: Jasmonic acid @ 50 µ M at 50 DAA and 75 DAA	2.91	2.61	2.76	3.50	3.08	3.29	3.90	3.92	3.91	3.02	3.07	3.05
T_{11}: Jasmonic acid @ 100 µ M at 50 DAA and 75 DAA	2.43	2.68	2.55	3.08	3.17	3.13	3.83	3.72	3.77	3.21	2.60	2.90
T_{12}: Jasmonic acid @ 150 µ M at 50 DAA and 75 DAA	2.41	2.79	2.60	3.66	2.93	3.30	3.82	3.35	3.58	3.21	3.41	3.31
T_{13}: Control	3.43	3.24	3.34	3.95	3.56	3.76	3.42	3.00	3.21	2.82	2.55	2.68
S.Em. ±	0.11	0.10	0.09	0.05	0.05	0.03	0.10	0.17	0.10	0.54	0.54	0.48
C.D. at 5%	0.31	0.29	0.25	0.14	0.14	0.10	0.30	0.49	0.29	NS	NS	NS

DAA: Days after anthesis

Table 6: Effect of pre-harvest spray of salicylic acid and jasmonic acid on sugar acid ratio 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	20.81	20.10	20.46	25.97	22.71	24.34	37.24	37.65	37.45	32.90	34.08	33.49
T_2: Salicylic acid @ 100 ppm at 50 DAA	18.78	17.96	18.37	25.31	20.75	23.03	39.36	38.06	38.71	36.47	37.70	37.08
T_3: Salicylic acid @ 150 ppm at 50 DAA	16.97	15.53	16.25	25.06	23.18	24.12	35.93	33.40	34.67	36.89	32.62	34.75
T_4: Jasmonic acid @ 50 µ M at 50 DAA	16.59	15.75	16.17	27.91	24.14	26.03	43.38	39.12	41.25	40.59	36.69	38.64
T_5: Jasmonic acid @ 100 µ M at 50 DAA	17.61	15.85	16.73	22.31	21.68	21.99	35.02	33.76	34.39	35.24	32.12	33.68
T_6: Jasmonic acid @ 150 µ M at 50 DAA	16.15	16.40	16.27	24.23	23.48	23.86	39.25	37.05	38.15	39.16	38.71	38.93
T_7: Salicylic acid @ 50 ppm at 50 DAA and 75 DAA	20.19	19.53	19.86	28.85	28.40	28.63	50.63	46.52	48.57	43.66	41.76	42.71
T_8: Salicylic acid @ 100 ppm at 50 DAA and 75 DAA	23.66	20.45	22.06	31.33	29.88	30.60	49.80	46.07	47.93	46.56	45.89	46.22
T_9: Salicylic acid @ 150 ppm at 50 DAA and 75 DAA	23.72	18.86	21.29	33.96	29.44	31.70	54.11	53.72	53.92	46.51	43.26	44.89
T_{10}: Jasmonic acid @ 50 µ M at 50 DAA and 75 DAA	19.90	16.59	18.24	27.86	29.08	28.47	42.71	41.48	42.10	38.19	37.46	37.83
T_{11}: Jasmonic acid @ 100 µ M at 50 DAA and 75 DAA	18.84	17.26	18.05	25.58	27.23	26.40	42.27	36.69	39.48	41.23	33.85	37.54
T_{12}: Jasmonic acid @ 150 µ M at 50 DAA and 75 DAA	18.37	16.19	17.28	27.18	26.87	27.03	41.71	35.63	38.67	38.59	37.59	38.09
T_{13}: Control	31.74	28.09	29.91	43.16	39.74	41.45	31.55	31.75	31.65	30.36	27.48	28.92
S.Em. ±	0.90	0.66	0.60	0.96	1.21	0.65	2.10	2.18	1.60	2.56	2.16	1.85
C.D. at 5%	2.61	1.93	1.74	2.82	3.52	1.90	6.12	6.37	4.67	7.47	6.29	5.41

DAA: Days after anthesis

In the present study, it was observed that, the Total sugars increased progressively during the storage period upto certain period and decreased thereafter. However, the rate of increase is rapid in control fruits, which might be due to faster ripening and quicker hydrolysis of starch into simple sugars up to 6 days of storage and high metabolism of senescence of fruit.

Wills *et al.* (1980) [19] also reported that, during ripening the starch is hydrolysed to mono and disaccharides resulting in increased TSS and Total sugars of the fruits. The gradual decline of TSS and Total sugars thereafter might be due to higher rate of respiration utilizing simple sugars initially and organic acids thereafter.

The increase of sugars by salicylic acid might be due to acceleration of the sugar translocation from leaves to the developing fruit by enhancing the activity of α-amylase enzyme by salicylic acid (Sharma *et al.*, 1986) [15]. Apart from that it was reported by Leclere *et al.*, 2003 that the hydrolysis of sucrose by invertase regulated mainly by the levels of some plant hormones like IAA, salicylic acid and jasmonic acid.

The delayed increase of TSS and sugars in salicylic acid treated fruits might be due to slower ripening rate of fruits caused by reduction of ethylene bio synthesis**.** A delayed increase of total sugars by salicylic acid treatment was also reported in peach (Khademi and Ershadi, 2013) [9], mango (Singh *et al.*, 2001, Shivendra and Singh, 2015) [16, 17], and Naqvi *et al.* (1998) [12] and strawberry (Salari *et al.*, 2012) [14].

In the present study at 9th day of storage it was observed that application of jasmonic acid at different concentrations improved total sugars of the fruits compared to control. Lower rates of respiration of papaya fruits treated with jasmonic acid might have contributed to conserve higher level of carbohydrates in tissue. Jasmonic acid Similar effect in increasing the TSS and sugars of the fruits was observed in fortune plums (Emine and Oztruk, 2014) [5] and strawberry (Ayala *et al.*, 2005) [2].

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