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The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(3): 448-455

www.thepharmajournal.com
Received: 13-01-2022
Accepted: 08-02-2022

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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

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Abstract
The present study was conducted to assess the pre-harvest application of elicitors and bio-formulations (Brassinosteriod @ 0.05%, Brassinosteriod @ 0.1%, Chitosan @ 2%, *Pseudomonas fluorescens* @ $1x10^8$cells/ml, *Bacillus subtilis* @ $1x10^8$cells/ml, Salicylic acid @ 300ppm, Clove oil @ 0.2%, Eucalyptus oil @ 0.2%) on papaya fruits at different development stages. The first spray was taken upat 2 months before harvest, 2nd and 3rd spray - 15 days after 1st and 2nd spray, respectively. The results indicated that, pre-harvest application of Salicylic acid @ 300ppm on among these treatments Salicylic acid @ 300ppm on Red Lady papaya fruits recorded high firmness and lowest physiological loss in weight, decreased respiration rate and Colour values (L^*, a^*, b^*) and thereby improve the fruit quality and Shelf life. The next best treatment was T_3 *i.e.,* papaya fruits sprayed with Brassinosteriod @ 0.1% also recorded similar to that of T_7, compared to control fruits sprayed by water alone (T_1) where it recorded highest physiological loss in weight (PLW), higher respiration rate and rapid increase in colour values. The percent disease index (PDI) was highest in control fruits, least in Salicylic acid @ 300ppm and Brassinosteriod @ 0.1% sprayed fruits.

Keywords: Elicitors, bio-formulations, physiological loss in weight, firmness, respiration rate, percent disease index, shelf life

Introduction

Papaya (*Carica papaya* L.) is also known as pawpaw belongs to the family Caricaceae. It is considered as one of the most popular fruits among the millions of people in the tropical and subtropical area due to it taste, nutrition value and medicinal use. It is regarded as the wonder fruit of the tropical and sub-tropical regions. It is originated in Mexico and it was introduced to India during 16th century from Malaca (Kumar and Abraham, 1943) [22]. India is the main papaya producing country, whereas, Mexico occupies the sixth place and provides about 37.10 per cent and 5.90 per cent of the total production, respectively (Anonymous, 2014) [4]. India has approximately 1.38 lakh hectares of land under papaya cultivation and produces around 59.89 million metric tons per year (Anonymous, 2018) [5]. Andhra Pradesh is the leader in papaya production among the Indian states followed by Karnataka, Gujarat and Maharashtra.

Papaya is a rich source of antioxidants nutrients. Each 100g of fruit contains 88.80 per cent moisture, 42.28 per cent starch, 15.50 per cent sugar but low levels of fat. Papaya fruit also contains high levels of vitamin C (61.8 mg), vitamin A precursors including β-carotene (276 µg) and β-cryptoxanthin (594.3 µg), as well as magnesium (10 mg) (Anonymous, 2004) [3]. Papaya is a highly perishable fruit and has a very short storage life at ambient condition. Physiologically, papaya fruits exhibit a climacteric behaviour. Postharvest losses of approximately 11 to 25 per cent have been generally reported in papaya in developing countries (Anonymous, 2014) [4].

The major constraint that hinder the expansion of export of papaya fruit are short storage life, susceptibility to postharvest diseases, high shipment cost and pesticide residues that is harmful to the human consumption. Post harvest fruit decay is a major constraint in post-harvest handlings causing decreases in both quantity and quality of produce in general. It is argued that, pre-harvest applications of microbial antagonist are often effective for the control of postharvest diseases (Ippolito and Nigro, 2000) [18]. Elicitors stimulate the different biotic and abiotic stress conditions and trigger the plant biochemical system towards increasing of secondary metabolites (Zhao *et al.*, 2005) [43].

They suggest that, treating the plants with elicitors could be a strategy of low risk to enhance the presence of these compounds in the plant. Hence, elicitors are effective in preserve the post-harvest quality of papaya fruits.A systematic study on evaluation and identification of suitable elicitors, bio-agents/bio-formulations and plant based products and its application at pre harvest and postharvest stage to delay ripening process, to reduce post harvest losses and to maintain the quality of fruit is very much essential. These elicitors/bio-formulations act as barrier for respiration, transpiration, arrest the growth of pathogens and ultimately lead to an increased shelf life and maintain the marketability of the fruit for a longer period.

Material and methods

Experimental details

The experiment was carried out at farmer field, Kaladagi hobli, Bagalkot district and Department of Post-harvest Technology, College of Horticulture, University of Horticultural Sciences Campus, Bagalkot, Karnataka during the year 2017-2018 with 9 treatments and 3 replications. The statistical design applied was completely randomized design (CRD). The treatment Details are T_1 - Control (water spray), T_2 - Brassinosteroid @ 0.05%, T_3 - Brassinosteroid @ 0.1%, T_4 - Chitosan @ 2%, T_5 - *Pseudomonas fluorescens* @ $1x10^8$cells/ml, T_6 -*Bacillus subtilis* @ $1x10^8$cells/ml, T_7 - Salicylic acid @ 300 ppm, T_8 - Clove oil @ 0.2%, T_9 - Eucalyptus oil @ 0.2%.

Elicitors/bio-formulations were sprayed as per the treatments at different fruit developmental stages i.e., 1st spray- 2 months before harvest, 2nd and 3rd spray - 15 days after 1st and 2nd spray, respectively. Mature fruits were harvested at 1 or 2 yellow streaks on the fruit and were wrapped with paper to prevent mechanical injury during transportation to laboratory. Then removed the covered papers from fruits, the pre harvest treated as well as control fruits were stored under ambient conditions for further observations. Five fruits were used in each replication for analysis of physical, physiological and biochemical parameters.

Parameters studied

Physiological loss in weight (%)

Fruits from each replication were taken to record the physiological loss in weight (PLW). The weight of the fruits was recorded using electronic weighing balance before storage. Thereafter, the weights were recorded regularly during storage and the PLW was calculated with the following formula and expressed as per cent physiological loss in weight.

$$\text{Physiological loss in weight (\%)} = \frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Initial weight (g)}} \times 100$$

Rate of respiration (ml CO_2/kg/h)

The rate of respiration was measured by static head space method using gas analyzer (PBI, Dansensor, Checkmate 2) and expressed as ml CO_2 kg^{-1} h^{-1}. For this, papaya fruit were trapped in 3 litre airtight containers having twist-top lid fitted with a silicone rubber septum at the centre of the lid. The containers were kept for 1 h for accumulation of respiratory gases at the headspace. After specified time, the head space gas was sucked to the sensor of the analyzer through the hypodermic hollow needle and the displayed value of evolution rate of CO_2 concentration (%) was recorded. Rate of respiration was calculated on the basis of rate of evolution of $CO_2$from the fruit per unit weight per unit time using the following formula.

$$\text{Rate of respiration (ml CO}_2\text{/kg/h)} = \frac{\text{CO}_2 \text{ concentration (\%) x Head space}}{100 \text{ x Weight of the fruit (Kg) x Time (h)}}$$

Fruit firmness (N)

Fruit firmness was determined using texture analyzer. Firmness evaluation was carried out by taking whole fruit with skin and penetrating it with a 2 mm diameter cylindrical needle. Three measurements were performed and values of the samples were averaged. Firmness is evaluated using a TAXT plus Texture Analyser (Make: Stable Micro System, Model: Texture Export Version 1.22). The force with which the sample gets penetrate was recorded in graph and the peak value in the graph was taken as the texture value in terms of Newton force (N). Firmness was defined as maximum force (kgf) required during the penetration, which was expressed in Newtons (N).

Colour (*L**, *a**, *b**)

Colour of the samples was measured using Lovibond colour meter (Model: Lovibond RT_300, Portable Spectrometer, the Tintometer Limited, Salisbury, UK) fitted with 8 mm diameter aperture. The instrument was calibrated using black and white tiles provided. Colour was expressed in Lovibond units *L** (lightness/darkness), *a** (redness/greenness), *b**(yellowness/blueness). Papaya sample was placed across the aperture of the colour meter. Three measurements were performed and values of the samples were averaged.

The colour of the papaya skin in terms of luminance (*L**), green or red colour (*a**) and blue or yellow colour (*b**) values were determined using a colorimeter. *L** measures lightness and varies from 100 for perfectly reflective white to zero for perfectly absorptive black; *a** measures redness when positive, gray when zero and greenness when negative; and *b** measures yellowness when positive, gray when zero and blueness when negative. Papaya fruits colour of skin was measured at three different points of each fruit.

Per cent disease index (PDI)

The per cent disease index was measured by visual inspection during storage. For the deterioration grade, the peel hydration, damage by mechanical and/or caused by fungi was considered based on the scale. 0-5 scale is used i.e.,0 – No lesions, 1 - 5% to ≤ 15 % lesions, 2 - ≥15% to ≤ 25 % lesions, 3 - ≥25% to ≤ 50 % lesions, 4 - ≥50% to ≤ 75 % lesions,5 - ≥75% to 100 % lesions. PDI was calculated with the following formula and expressed as per cent disease index (Narasimhudu, 2007) [24].

$$\text{PDI (\%)} = \frac{\text{Sum of all disease rating}}{\text{Total number of rating x Maximum disease grade}} \times 100$$

Shelf life

The number of days of the ripe fruits were in edible condition was taken as the shelf-life or keeping quality of ripe fruits.

Results and Discussion

Physiological loss in weight (%)

Physiological loss in weight refers to loss in weight of the produce due to physiological processes such as transpiration and respiration. Transpiration is a mechanism in which water is lost due to difference in the vapour pressure of the water in the atmosphere and the transpiring surface, whereas respiration is a catabolic activity involving oxidation of complex substrates resulting in the formation of CO_2 molecule released into the atmosphere. Physiological loss in weight is one of the important economic parameter that decides the shelf life even if fruit is free from physical and microbial abuse. They appear shriveled, shrunk, misshaped, lose its crispness, flavour, turgour and other organoleptic qualities.

The physiological weight loss of papaya fruits was observed to increase with ripening process. There was a significant difference among the treatments as affected by the pre harvest application with elicitors and bio-formulations. Among the various pre harvest treatments, the control (T_1) fruits lost maximum weight of 21.30 per cent during 9 days of storage. Whereas, pre harvest fruits treated withSalicylic acid (SA) at 300 ppm were lost minimum weight of 13.99 per cent during 9th day.

The physiological loss in weight results mainly by the respiration and transpiration losses during the metabolic processes of fruits coupled with by atmospheric storage conditions in terms of low relative humidity triggers the pressure difference between fruits and surrounding storage condition (Baile, 1975; Finger and Vieira, 1997) [8, 13]. Salicylic acid (SA) has been reported to close stomata, which results in suppressed respiration rate and minimized weight loss of fruits according to Zheng and Zhang (2004) [44]. Similarly, peach fruits cv. 'Delicia' treated with SA exhibited less weight loss than control in peach (Abbasi *et al.,* 2010; Wang *et al.,* 2006) [1, 37]. Higher PLW in untreated fruits might be due to lack of physical barrier leading to the more transpiration and gaseous exchange results to maximum weight loss. Similar results of reduced weight loss and delayed ripening have been reported in peach (Brar *et al.,* 2014) [9], in tomato (Nirupama *et al.,* 2010) [25], in kiwifruit (Jawad *et al.,* 2010) [20], in apple (Kazemi *et al.,* 2011) [21].

Firmness (N)

The control fruits recorded lowest firmness of 0.56 N during 9th day of storage. While, pre harvest fruits treated withSalicylic acid at 300 ppm showed highest firmness of 4.34 N during 9th day of storage.

The firmness of the fruit tissue at harvest is mainly due to the physical properties of the individual cell walls and the middle lamella, which contains the cementing pectic material. As the fruit approaches ripening, the firmness decreases with the increase in storage period, primarily because there might have been progressive increase in fruit softening due to increased activities of lipoxygenase (LOX), polygalactrose (PG) and pectinmethylesterase (PME) enzymes, rendering much softer with increase in storage period (Sharma *et al.,* 2012) [33]. The soluble pectin is much higher where higher temperature or no CO_2 are involved. The rate of pectin degradation is affected by both time and conditions of storage by Salunkhe *et al.* (2000) [29]. Santos *et al.* (2008) [31] observed the existence of a relation between mass loss and fruit firmness, that is, whenever there is an increase in percentage of mass loss, there is also a reduction in firmness. In the present study, there was a significant decrease in firmness of papaya fruits as the storage period increase and fruits started ripening at faster rate under room temperature. These results were in conformation with the results reported by Reboucas *et al.* (2013); Correa *et al.* (2010); Islam (2012); Bron and Jacomino (2006); Hendriod *et al.* (2012) [27, 12, 19, 10, 17] in papaya. Fruit firmness is one of the most crucial factors in determining the postharvest quality of fruits (Shear, 1975) [34]. In the present study, softening of papaya fruits were remarkably delayed with Salicylic acid treatment during ambient storage period.

Salicylic acid is also reported to have positive effects in maintaining the maximum firmness. Salicylic acid treatments and especially fruits treated with SA at 300 ppm concentration were more firm. Softening of fruits is a main and critical quality change. Positive effect of salicylic acid on fruit firmness has been previously reported (Shafiee *et al.,* 2010; Ranjbaran *et al.,* 2011) [32, 26]. According to Srivastava and Dwivedi (2000) [35] in banana, Zhang *et al.*(2007) [42] in kiwi fruit and Wang *et al.* (2006) [37] in peach fruit, rapid softening of fruits during ripening was simultaneous with rapid decrease in endogenous salicylic acid of fruits and exogenous application of salicylic acid preventing fruit softening. Salicylic acid affects cell swelling, which lead to higher firmness of fruits as reported by Zhang *et al.* (2007) [42] in kiwi fruit. Softening of peach as a climacteric fruit depends on the internal ethylene production. It has been demonstrated that, SA decreases ethylene production and inhibits cell wall and membrane degrading enzymes such as polygalacturonase, lipoxygenase, cellulase and pectin methyl esterase, leading to decreased fruit softening rate (Asgharia and Aghdam, 2010) [6].

Respiration rate (ml CO_2 kg^{-1} h^{-1})

The respiration rate of papaya fruits increased gradually in all the pre harvest treatments. It was observed that, a significant difference among the treatments with respect to respiration rate during storage. The maximum respiration rate was recorded in control (24.35ml CO_2/kg/hr) and minimum respiration rate was recorded in Salicylic acid at 300 ppm (11.58 ml CO_2/kg/hr), because salicylic acid could delay ripening of fruits, probably through inhibition of ethylene biosynthesis or its action (Wang and Li, 2008) [38].

It is well known that, any factor increasing ethylene production or activity leads to increase in respiration rate and any factor increasing respiration rate leads to increase in ethylene production and activity (Wills *et al.,* 1998) [40]. It has been demonstrated that, salicylic acid (SA) in a concentration dependent manner effectively reduces the respiration in plants and harvested fruits (Han *et al.,* 2003; Srivastava and Dwivedi, 2000; Wolucka *et al*., 2005) [16, 35, 41]. Decrease in fruit metabolic activities results in a decrease in fruit water loss and carbohydrate depletion rate and consequently, effectively delays fruit senescence process (Wills *et al.,* 1998) [39]. Salicylic acid has also been reported to inhibit ethylene biosynthesis in plants by blocking the conversion of 1- amino-cyclopropane-1-carboxylic acid (ACC) to ethylene and is known to reduce the rate of respiration and ethylene production (Renhua *et al.,* 2008) [28]. In strawberry fruit, SA treatment at all concentrations effectively reduced fruit ethylene production and retained overall quality. Treatment of plants at vegetative stage and fruit development stage followed by postharvest treatment of fruits was the most effective (Babalar *et al.,* 2007) [7]. Lu *et al.* (2010) [23] reported that, pineapple fruits treated with salicylic acid significantly decreased the tissue respiration rate due to activities of peroxidase, polyphenol oxidase and phenylalanine ammonia lyase decreased with this treatment.

Table1: Effect of pre harvest application of elicitors and bio-formulations on physiological loss in weight (%), firmness (N) and respiration rate (ml CO_2/kg/h) during ambient storage of papaya fruit

Treatment details	Physiological loss in weight (%)				Firmness (N)				Respiration rate (ml CO_2/kg/h)				Shelf life (days)
	Days of storage				Days of storage				Days of storage				
	3	5	7	9	3	5	7	9	3	5	7	9	
T_1 - Control (waterspray)	3.98	8.68	14.74	21.30	4.13	2.93	1.24	0.56	13.08	15.30	18.54	24.35	7.00
T_2 - Brassinosteroid @ 0.05%	2.66	4.91	10.78	16.28	7.12	5.93	4.35	3.03	8.51	9.38	12.55	14.63	8.33
T_3 - Brassinosteroid @ 0.1%	2.40	4.20	9.75	14.61	7.46	6.59	5.26	3.92	8.02	8.61	11.80	12.85	9.00
T_4 - Chitosan @ 2%	2.56	4.80	10.53	15.66	7.33	6.08	4.63	3.28	8.34	8.93	12.16	14.15	8.66
T_5 - *Pseudomonas fluorescens* @ 1 x 10^8 cells/ml	3.03	6.0	12.07	17.46	4.97	3.94	2.46	1.63	9.87	11.07	13.62	16.07	8.33
T_6 - *Bacillus subtilis* @ 1 x 10^8cells/ml	3.43	7.56	13.38	18.88	4.73	3.59	2.08	1.16	11.09	12.47	14.42	17.41	8.00
T_7 - Salicylic acid @ 300 ppm	2.26	3.6	8.19	13.99	7.69	7.15	5.66	4.34	7.58	8.10	10.29	11.58	9.00
T_8 - Clove oil @ 0.2%	2.74	5.11	10.93	16.41	6.92	5.73	4.17	2.95	8.83	9.79	12.87	15.11	8.66
T_9 - Eucalyptus oil @ 0.2%	2.80	5.50	11.33	16.95	6.72	5.20	3.73	2.57	9.18	10.20	13.25	15.50	8.66
S.Em±	0.04	0.10	0.09	0.13	0.07	0.09	0.06	0.04	0.09	0.09	0.10	0.12	0.18
CD at 1%	0.18	0.43	0.38	0.56	0.27	0.36	0.24	0.17	0.39	0.36	0.43	0.49	0.74

Instrumental colour values

The *L** value of control (T_1) fruits rapidly increased and reached the maximum value of 64.28 during 9th day of storage. In ambient storage condition, the *L** value of salicylic acid at 300 ppm pre-harvest treated papaya fruits showed lowest *L** value of 50.75 followed by T_3 (Brassinosteroid at 0.1%) treated fruits showed *L** value of 52.04 at 9th day of storage. The *a** value of control (T_1) fruits rapidly increased and reached the peak during 9 days of storage with 17.39. In this experiment, the fruits pre harvest treated with Salicylic acid at 300 ppm showed a lowest *a** value of 6.93 followed by T_3 (7.68) in 9th day of storage. The *b** value of control fruits increased and reached a maximum value of 57.04 in ambient storage at 9th day. In these study, the *b** value of salicylic acid at 300 ppm treated papaya fruits showed lowest *b** value of 36.17 at 9th day of storage.

Papaya fruits treated with Salicylic acid at 300 ppm recorded lesser colour change than control fruits as evident from the instrumental colour values. During ripening, the fruit goes through biochemical, physiological and structural changes such as an increase in TSS, pulp softening and change in coloration. Change in coloration is the visual symptom of ripening. As fruits ripen the chlorophyll degradation takes place and senescence begins, which is an irreversible process. The green colour is due to the presence of chlorophyll, which is a magnesium-organic complex. The principal agents responsible for this degradation are pH changes *i.e.* mainly due to leakage of organic acids from vacuoles, oxidative system and enzyme chlorophyllase. Loss of colour depends on one or all of these factors acting in sequence to destroy the chlorophyll structure. The similar result was observed in papaya fruits treated with salicylic acid and recorded minimum loss of chlorophyll in the peel. Variation of peel colour in papaya as a reference of maturation stage is also explained by Fonseca *et al.* (2007) [14] and Sancho *et al.* (2010) [30]. This may be due to pre harvest treatment of fruits treated with Salicylic acid could have delayed the degradation of chlorophyll and reduced the softening of papaya fruits by reduced rate of respiration. Higher loss in green colour in control (untreated) fruits may be caused by increased breakdown of chlorophyll and synthesis of β- carotene pigments, which occur during ripening. The Salicylic acid treatment resulted in slow rate of respiration and reduced ethylene production. This is in-turn delayed the ripening and senescence of the fruit, resulting in reduced colour change. Similar results have been reported in peach by Tareen *et al.* (2012) [36].

Table 2: Effect of pre harvest application of elicitors and bio-formulations on colour (*L**, *a**, *b**) values during ambient storage in papaya fruit.

Treatment details	Colour (*L**) values				Colour (*a**) values				Colour (*b**) values			
	Days of storage				Days of storage				Days of storage			
	3	5	7	9	3	5	7	9	3	5	7	9
T_1 - Control (water spray)	45.53	50.61	60.03	64.28	- 6.21	4.56	10.05	17.39	21.50	38.15	48.03	57.04
T_2 - Brassinosteroid @ 0.05%	43.76	46.23	49.22	53.85	- 6.77	- 2.23	2.76	9.22	18.06	28.22	36.00	40.53
T_3 - Brassinosteroid @ 0.1%	43.59	45.46	48.37	52.04	- 7.03	- 4.33	2.08	7.68	17.61	25.15	33.30	37.53
T_4 - Chitosan @ 2%	43.67	45.92	49.07	53.04	- 6.89	- 3.59	2.44	8.71	18.42	27.79	34.61	39.46
T_5 - *Pseudomonas fluorescens* @ 1 x 10^8 cells/ml	44.24	47.35	52.00	58.08	- 6.65	1.70	4.43	10.42	19.78	32.39	40.32	44.97
T_6 - *Bacillus subtilis* @ 1 x 10^8cells/ml	44.41	48.32	54.31	58.94	- 6.34	1.91	4.75	11.09	20.15	34.00	43.43	46.17
T_7 - Salicylic acid @ 300 ppm	43.07	44.70	46.78	50.75	- 7.41	- 4.69	1.28	6.93	17.19	23.11	29.19	36.17
T_8 - Clove oil @ 0.2%	43.94	46.44	50.00	55.12	- 6.79	- 1.55	3.28	9.38	18.56	29.65	36.36	42.10
T_9 - Eucalyptus oil @ 0.2%	44.09	46.93	50.99	56.65	- 6.54	- 1.30	3.82	9.65	19.19	31.46	38.01	43.91
S.Em±	0.18	0.25	0.25	0.33	0.06	0.09	0.08	0.18	0.16	0.20	0.27	0.12
CD at 1%	0.75	1.02	1.03	1.35	0.27	0.39	0.32	0.76	0.65	0.84	1.12	0.48

Per cent disease index (PDI)

The per cent disease index (PDI) of control fruits rapidly increased and reached the maximum of 94.44 per cent at 9th day of storage. The PDI of papaya fruits treated with T_7 (SA at 300 ppm) showed the lowest value of 34.83 per cent in 9th day of storage.

This was mainly due to pre-harvest treatments with Salicylic acid reduced the lesion diameters on fruit caused by fungi and induced ß-1, 3-glucanase, phenylalanine ammonia-lyase (PAL) and peroxidase activities during storage. SA shows direct toxicity on fungi and significantly inhibits fungal growth and spore germination of the pathogen invitro. Exogenous application of salicylic acid or methyl-salicylic acid may also induce the expression of many defense genes during fruit storage. Pre-storage or pre harvest application of salicylic acid may provide a useful means of controlling postharvest decay there by extending the storage life (Wang and Li, 2008) [38]. Plant treatment at both vegetative and fruit development stages resulted in significant decrease of fungal decay confirming the fact that, SA leads to plant defense system activation against pathogens. SA causes a rapid increase in H_2O_2 production in plants and H_2O_2, as a signal molecule activates the plant's systemic resistance against pathogens (Cai and Zheng, 1999) [11]. The inhibitory effects of postharvest fruit treatment with SA on fungal decay confirm the previous reports about its antifungal effects (Amborabe *et al.*, 2002; Goetza *et al.*, 1999) [2, 15] showing that, SA directly prevents decay of fruits by fungi growth and extension in strawberry fruits. SA treatment effectively controlled the fruit fungal decay and decreased ethylene production leading to absence of any decay on fruit (Wills *et al.*, 1998) [40]. Since, it was more effective when successively applied at vegetative + fruit development + postharvest stages, like its effects on other fruit attributes the effect of SA on overall quality is reversible and also cumulative. Thus, salicylic acid a natural and safe phenolic compound, exhibits a high potential in controlling postharvest losses of Selva strawberry fruits (Babalar *et al.*, 2007) [7].

Shelf life (days)

Shelf life of papaya fruit is interconnected with broader physical, physiological, physico-chemical and microbiological parameter. Each parameter has its own impact on fruit quality and storage life. However, present study was tried to address one factor, in physiology of papaya fruits by pre-harvest application of elicitors and bio-formulations on fruits at different fruit development stages.

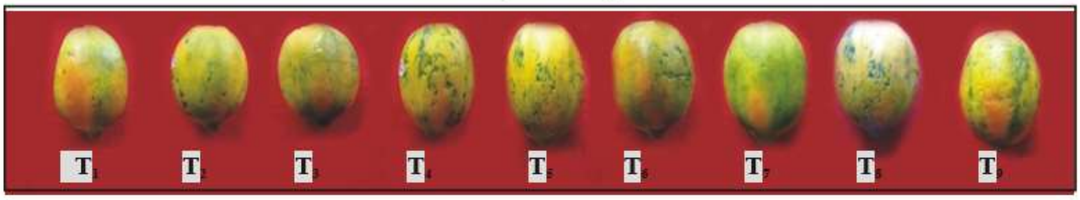
The papaya fruits sprayed with Salicylic acid at 300 ppm (T_7) and (Brassinosteroid @ 0.1% (T_3) showed an extended storage period upto 9 days under ambient storage when compared to control fruits (7days) is presented in Table1.This extension of storage period was due to the delay in the ripening process caused by elicitors and bio-formulations. Among the elicitors and bio-formulations, SA was effectively reduced respiration in plants and harvested fruits (Han *et al.*, 2003; Srivastava and Dwivedi, 2000) [16, 35]. Pre-storage or pre harvest application of Salicylic acid may provide a useful means of controlling postharvest decay thereby extending the storage life (Wang and Li, 2008) [38]. Similarly, Brassinosteroid significantly delayed the fruit senescence by reducing ethylene production, respiration rate and maintained fruit quality. It is suggested that the effects of Brassinosteroid on reducing decay caused by *Pencillium expansum* may be associated with induction of disease resistance in fruit and delay of senescence leading to enhancement of the shelf life (Zhua *et al.*, 2010) [45].

Table 3: Effect of pre harvest application of elicitors and bio-formulations on per cent disease index (PDI) on 9th day of papaya fruit stored under ambient condition

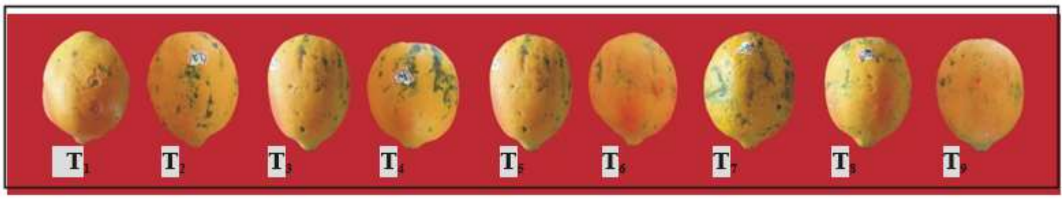
Treatment details	Per cent disease index (PDI)
T_1 - Control (water spray)	95.84
T_2 - Brassinosteroid @ 0.05%	42.66
T_3 - Brassinosteroid @ 0.1%	37.00
T_4 - Chitosan @ 2%	44.00
T_5 - *Pseudomonas fluorescens* @ 1 x 10^8 cells/ml	51.00
T_6 - *Bacillus subtilis* @ 1 x 10^8cells/ml	58.66
T_7 - Salicylic acid @ 300 ppm	34.83
T_8 - Clove oil @ 0.2%	39.00
T_9 - Eucalyptus oil @ 0.2%	40.16
S.Em±	0.42
CD at 1%	1.72

1 day of storage

3 day of storage

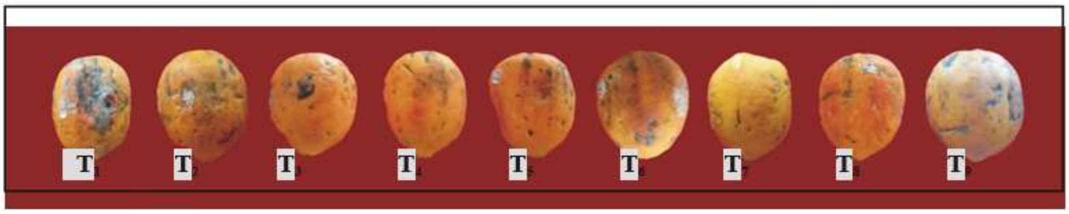


5 day of storage



7 day of storage

9 day of storage

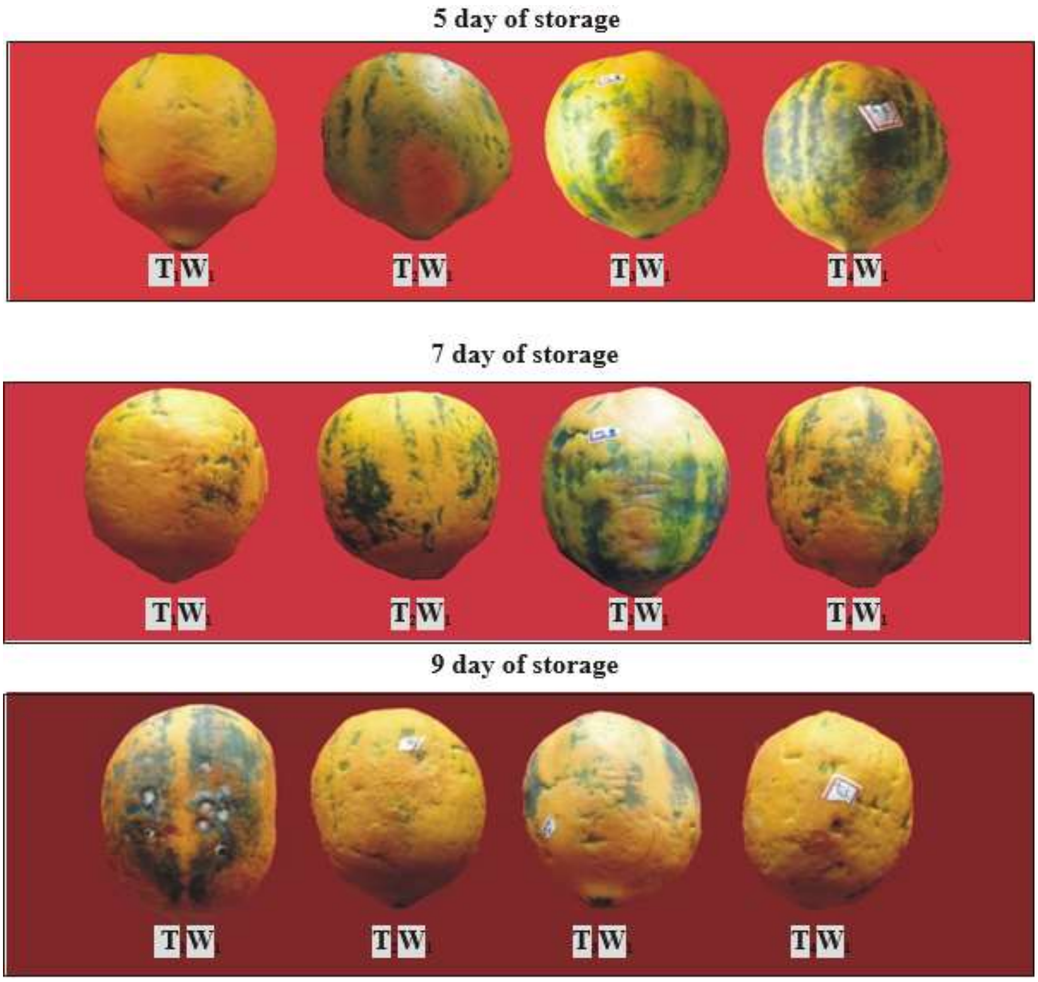


T1: Control (water spray)
T2: Brassinosteroid @ 0.05%
T3: Brassinosteroid @ 0.1%
T4: Chitosan @ 2%
T5: *Pseudomonas fluorescens* @ 1x108 cells/ml
T6: *Bacillus subtilis* @ 1x108 cells/ml
T7: Salicylic acid @ 300 ppm
T9: Eucalyptus oil @ 0.2%
T8: Clove oil @ 0.2%

Plate 1: Effect of pre-harvest application of elicitors and bio-formulations on shelf life and quality of papaya fruit during storage period

1 day of storage

3 day of storage



W1: Fruits without paper wrapping **T1:** Control (water spray)
T2: Brassinosteroid @ 0.1% **T3:** Chitosan @ 2% **T4:** Salicylic acid @ 300 ppm

Plate 2: Effect of combined pre and post-harvest treatments of elicitors and bio- formulations without wrapping paper on shelf life and quality of papaya fruit during storage period

Conclusion

Results revealed that pre-harvest application of Salicylic acid treatment influence on physical and physiological quality characteristics and also decrease the percent disease index of papaya fruit. The prearrest foliar application of salicylic acid was found to be more effective as compared to control fruits due to significant reduction of physiological loss in weight, fruit softening, respiration rate, colour change, per cent disease index and enhanced shelf life and quality of papaya fruits when compared to control. pre harvest application of salicylic acid may provide a useful means of controlling postharvest decay there by extending the storage life and delayed the degradation of chlorophyll and reduced the softening of papaya fruits by reduced rate of respiration Plant treatment at fruit development stages resulted in significant decrease of fungal decay confirming the fact that, SA leads to plant defense system activation against pathogens.

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