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Effects of salicylic acid on postharvest physiology of tomato

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ABSTRACT

Exogenous application of salicylic acid (SA) was studied during postharvest ripening of tomato fruits. Green mature fruits of tomato (*Solanum lycopersicon* L. cvs. Pusa Rohini and Pusa Gaurav) were dipped in SA at 0.5, 0.75 and 1.0 mM and control double-distilled water at 20°C for 15 min. The various traits, *viz.* weight loss percentage, mineral content (Ca, Zn and Cu), climacteric respiration, ethylene production and ethylene biosynthetic enzymes activity (ACS and ACO) were studied at 5-7 day intervals. It was found that the SA (0.75 mM) dip treatment delayed and suppressed climacteric respiration, ethylene biosynthesis and increased the shelf-life of tomato fruits by seven days. Moreover, reduced weight loss percentage and optimum content of Ca, Zn and Cu with respect to control and other SA treatments support the prolongation of the process of ripening.

Key words: Ethylene, post-harvest physiology, salicylic acid, tomato.

INTRODUCTION

Tomato fruit ripening involves various biochemical and physiological changes that provide desirable flavour, aroma, texture, quality to the fruit and it becomes edible as a raw. But one of the limiting factors that influence their economic value is the reduced postharvest life due to relatively short ripening period. The major physiological trait that regulates ripening in climacteric fruits such as tomato, apple, banana, mango, etc., is gaseous hormone ethylene and regulation of this hormone affects other ripening up regulating factors like climacteric respiration, softening enzymes etc. Previous literature suggested that salicylic acid and its derivative acetylsalicylic acid regulate ripening of various fruits and prolonged their shelf-life because it delayed and suppressed ethylene production and its biosynthetic enzymes activities, *viz.*, 1-aminocyclopropane-1-carboxylic acid synthase (ACS) and 1-aminocyclopropane-1-carboxylic acid oxidase (ACO), at early stages of ripening in harvested fruits like apple (Fan and He, 2), banana (Srivastava and Dwivedi, 9) as well as kiwi (Zhang *et al.*, 10).

Mineral content affects ripening behaviour and quality of tomato fruit. The presence of Ca supports the maintenance of the cell wall integrity and membrane permeability while Zn and Cu require as metal cofactors for enzymatic antioxidants. Thus, these minerals play important roles in stabilizing the plasma membrane and cell wall along with their involvement in the antioxidative defense system, and thereby determining the rate of ripening process of tomato (Paul and Srivastava, 7). On the basis of studied physical traits the two tomato cultivars, *viz*., Pusa Gaurav and Pusa Rohini have been shown, slow and fast ripening behaviour, respectively (Kant *et al.*, 3). Therefore, further study carried out with the effects of different concentrations of exogenous SA on climacteric respiration, ethylene production, activity of ACS and ACO, and contents of Ca, Zn and Cu in these two tomato cultivars *viz-a-viz* enhance the longevity of fruits.

MATERIALS AND METHODS

The two tomato cultivars were grown in spring season as commercial cultivation at Research Farm of Division of Vegetable Science, IARI, New Delhi. Uniform sized fruits from cultivars, *viz*., Pusa Gaurav and Pusa Rohini were harvested at green mature stage. After harvesting, fruits were cleaned, washed and dried at room temperature. These fruits were dipped in 0.5, 0.75 and 1.0 mM SA solution separately at 20°C for 15 min. as treatments and double distilled water (DDW) used for controls. They were kept separately at a room temperature of 20 ± 1°C and relative humidity 70 ± 5%. Various traits were measured at 5-7 day intervals after treatment according to attainment of their ripening stage, *i.e.*, breaker, turning, pink and red in untreated/ control as well as treated tomato fruits.

The shelf-life of tomato fruits was calculated by counting the days from treatments to the last stage of ripening, but up to the stage when they remained still acceptable for marketing on the basis of firmness and decay. The weight loss percentage

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(WLP) of fruits was calculated by considering the differences between initial weight at the day of treatments and final weight at the day of last stage of ripening divided by their initial weight. Determination of Ca, Cu and Zn were done following the method described by Paul and Srivastava (7) with the help of flame photometer for Ca (622 nm) and atomic absorption spectrophotometer for Cu (324.8 nm) and Zn (213.9 nm) and they were expressed as µg 100 g^{-1} FW. Estimation of ethylene production and climacteric respiration were done by gas chromatograph (DANI GC, Model-1000). Ethylene production was expressed as µmol kg^{-1} fw h^{-1} and climacteric respiration expressed as µmol CO_2 g^{-1} fw h^{-1}. The ACS and ACO activities were determined by following the method of Mathooko *et al.* (5) with minor modifications. The protein content of all the samples was determined using bovine serum albumin (BSA) as a standard.

Data represent the means and standard error mean, and the experimental design was completely randomized. Data were further subjected to analysis of variance and means were compared using least significance difference (LSD) at the P ≤ 0.05 level.

RESULTS AND DISCUSSION

Shelf-life of Pusa Rohini and Pusa Gaurav extended significantly upto 22 and 24 days, respectively with SA (0.75 mM) treatment in comparison to other treatments (0.5 and 1 mM) and untreated/ control fruits (Table 1). The effects of SA (0.75 mM) on weight loss was considerably more pronounced than other treatments and it was 26.07 and 26.52% lower than control at 22nd and 24th day in Pusa Rohini and Pusa Gaurav, respectively (Table 2). Thus, SA (0.75 mM) treatment prolonged the shelf-life by seven days and delayed the reduction in weight loss in both cultivars as compared with untreated/ control fruits. The similar conclusion were shown with application of SA on apple (Kazemi *et al.*, 4), banana (Srivastava and Dwivedi, 9) and kiwi fruit (Zhang *et al.*, 10) where SA prolonged the shelf-life of fruits as well as maintained the quality. Our results found conformity with the research on tomato (Pila *et al.*, 8) and apple (Kazemi *et al.*, 4), where SA could be able to reduce the weight loss and maintained the fruit firmness due to its antitranspirant as well as suppressing softening enzymes activity through inhibition of ethylene. In present study, of the three elements analyzed, one macro-element (Ca) and other micro-element (Zn and Cu) and it was found that Ca relatively increased, while Zn and Cu relatively reduced as the fruits attained maturity and ripening (Table 3). The SA (0.75 mM) treated fruits showed higher content of these nutrients by seven days longer than untreated/control and other treatments (Table 3). To our knowledge, this is the first report, where SA could be able to maintain the nutrient content of tomato fruits and support the prolongation of their shelf-life. The maintained content might be able to retain the cell wall integrity

Table 1. Effect of postharvest SA treatments on shelf life of tomato fruits of cv. Pusa Rohini and Pusa Gaurav.

Cultivar	Control	T_1	T_2	T_3
Pusa Gaurav	17.70 ± 0.29	17.36 ± 0.169	24.53 ± 0.205	17.13 ± 0.24
Pusa Rohini	15.56 ± 0.205	15.53 ± 0.249	22.6 ± 0.163	15.46 ± 0.169

LSD (P ≤ 0.05). Control (DDW); T1 = 0.50 mM; T2 = 0.75 mM; T3 = 1.0 mM.

Table 2. Effect of postharvest SA treatments on weight loss percentage of tomato fruits cv. Pusa Rohini and Pusa Gaurav.

Days after treatment	Cultivar	Control	T_1	T.	T_3
0	Pusa Gaurav	4.27 ± 0.049	4.34 ± 0.053	1.92 ± 0.042	4.33 ± 0.064
5	Pusa Rohini	4.38 ± 0.031	4.41 ± 0.070	2.1 ± 0.03	4.52 ± 0.102
10	Pusa Rohini	8.64 ± 0.056	8.67 ± 0.094	4.38 ± 0.046	8.75 ± 0.071
12	Pusa Gaurav	7.75 ± 0.066	7.81 ± 0.0962	4.61 ± 0.086	7.9 ± 0.0531
15	Pusa Rohini	10.53 ± 0.077	10.44 ± 0.054	6.47 ± 0.036	10.53 ± 0.1
17	Pusa Gaurav	10.77 ± 0.056	10.84 ± 0.039	6.65 ± 0.05	10.9 ± 0.043
22	Pusa Rohini	35.35 ± 0.075	35.38 ± 0.0641	9.28 ± 0.056	35.49 ± 0.096
24	Pusa Gaurav	34.75 ± 0.053	34.66 ± 0.909	9.23 ± 0.073	34.61 ± 0.149

LSD (P ≤ 0.05). Control (DDW); T1 = 0.50 mM; T2 = 0.75 mM; T3 = 1.0 mM.

Table 3. Effects of postharvest SA on Ca, Cu and Zn contents of tomato fruits (A) Pusa Rohini (B) Pusa Gaurav.

Days after treatment	Cultivar	Ca (µg 100 g^{-1} fw)				Zn (µg 100 g^{-1} fw)				Cu (µg 100 g^{-1} fw)			
		Control	T_1	T_2	T_3	Control	T_1	T_2	T_3	Control	T_1	T_2	T_3
5	Pusa Gaurav	11.11 ± 0.49	10.75 ± 0.78	10.79 ± 0.55	11.09 ± 0.87	630.33 ± 5.01	631.33 ± 3.89	714.33 ± 4.96	632 ± 5.33	387.33 ± 4.32	386.33 ± 5.30	492 ± 3.24	387.66 ± 4.26
	Pusa Rohini	11.41 ± 0.82	11.69 ± 0.79	11.89 ± 0.52	12.06 ± 0.54	569.66 ± 2.49	563.33 ± 3.68	663.33 ± 3.55	629.66 ± 4.78	362.33 ± 3.68	361.66 ± 3.85	424.33 ± 4.98	362.66 ± 3.29
10	Pusa Rohini	15.33 ± 0.83	14.95 ± 1.33	13.64 ± 0.59	14.76 ± 0.48	387.66 ± 4.18	381.66 ± 2.49	463.66 ± 2.49	477.33 ± 3.85	322.33 ± 3.39	321.33 ± 4.49	349.33 ± 4.18	323 ± 3.26
12	Pusa Gaurav	14.67 ± 0.70	14.41 ± 0.90	13.93 ± 0.49	14.48 ± 0.71	478.66 ± 6.12	484.33 ± 4.98	528.66 ± 4.10	478.66 ± 5.31	344.66 ± 2.86	343.66 ± 4.18	366 ± 3.74	345.66 ± 4.10
15	Pusa Rohini	20.66 ± 1.07	20.38 ± 0.86	17.34 ± 0.75	21.14 ± 0.72	290.66 ± 3.85	281.33 ± 4.10	455 ± 5.35	350.33 ± 4.64	244.66 ± 4.18	245.66 ± 5.31	304.33 ± 4.10	245.33 ± 3.29
17	Pusa Gaurav	21.18 ± 0.65	20.88 ± 1.12	16.46 ± 0.66	21.21 ± 0.69	351.33 ± 4.49	351.66 ± 3.29	442.66 ± 3.68	352.66 ± 4.10	267.66 ± 4.10	268 ± 4.54	324.66 ± 4.92	268.33 ± 4.10
22	Pusa Rohini	3.56 ± 0.30	3.74 ± 0.39	22.52 ± 0.60	3.87 ± 0.36	51.66 ± 2.86	54.66 ± 2.49	334.66 ± 2.49	54.66 ± 3.29	38.33 ± 2.49	38 ± 2.94	242 ± 3.74	37.66 ± 2.49
24	Pusa Gaurav	4.51 ± 0.27	4.38 ± 0.69	23.67 ± 0.66	4.17 ± 0.22	50.66 ± 2.27	51.33 ± 2.16	356.66 ± 3.18	52.33 ± 2.48	35.66 ± 1.47	35.33 ± 1.77	254.33 ± 4.32	35.66 ± 2.16

and texture of fruits. The presence of metal co-factors of enzymatic antioxidants, *viz*., Cu and Zn might suppress the oxidative stress in ripening fruits indirectly and prevent the damage of membrane and ion leakage of tomato fruits. Srivastava and Dwivedi (9) reported that reduced oxidative stress in banana with SA treatment led to prolongation of shelf-life with respect to control.

Ethylene production and climacteric respiration rate increased during ripening, and reached maximum at 10th day in Pusa Rohini (Fig. 1A and 1C) and 12th day in Pusa Gaurav (Fig. 1B and 1D), respectively in untreated/control and other treatments after that they gradually declined. The SA (0.75 mM) treated fruit exhibited maximum ethylene production and climacteric respiration at 15th and 17th day in Pusa Rohini (Fig. 1A and 1C) and Pusa Gaurav (Fig. 1B and 1D), respectively and then progressively declined. Mathooko *et al.* (5) reported that respiration of harvested crops is highly dependent on ethylene production and any factor increasing the production of ethylene led to increase in respiration and consequently increases the ripening of fruits. Exogenous application of SA reduces respiration rate as well as oxidative stress of several horticultural crops leading to delay of fruit ripening and senescence (Fan and He, 2). Previous research work on banana (Srivastava and Dwivedi, 9) suggested that SA delayed and suppressed the climacteric respiration as well as ethylene production in early stages of fruit ripening. The present research work on ethylene production is consistent with research work on kiwi (Zhang *et al*., 10) as well as apple (Mo *et al*., 6), where exogenous SA suppressed the ethylene and that led to reduction of climacteric respiration and suppression of softening enzymes.

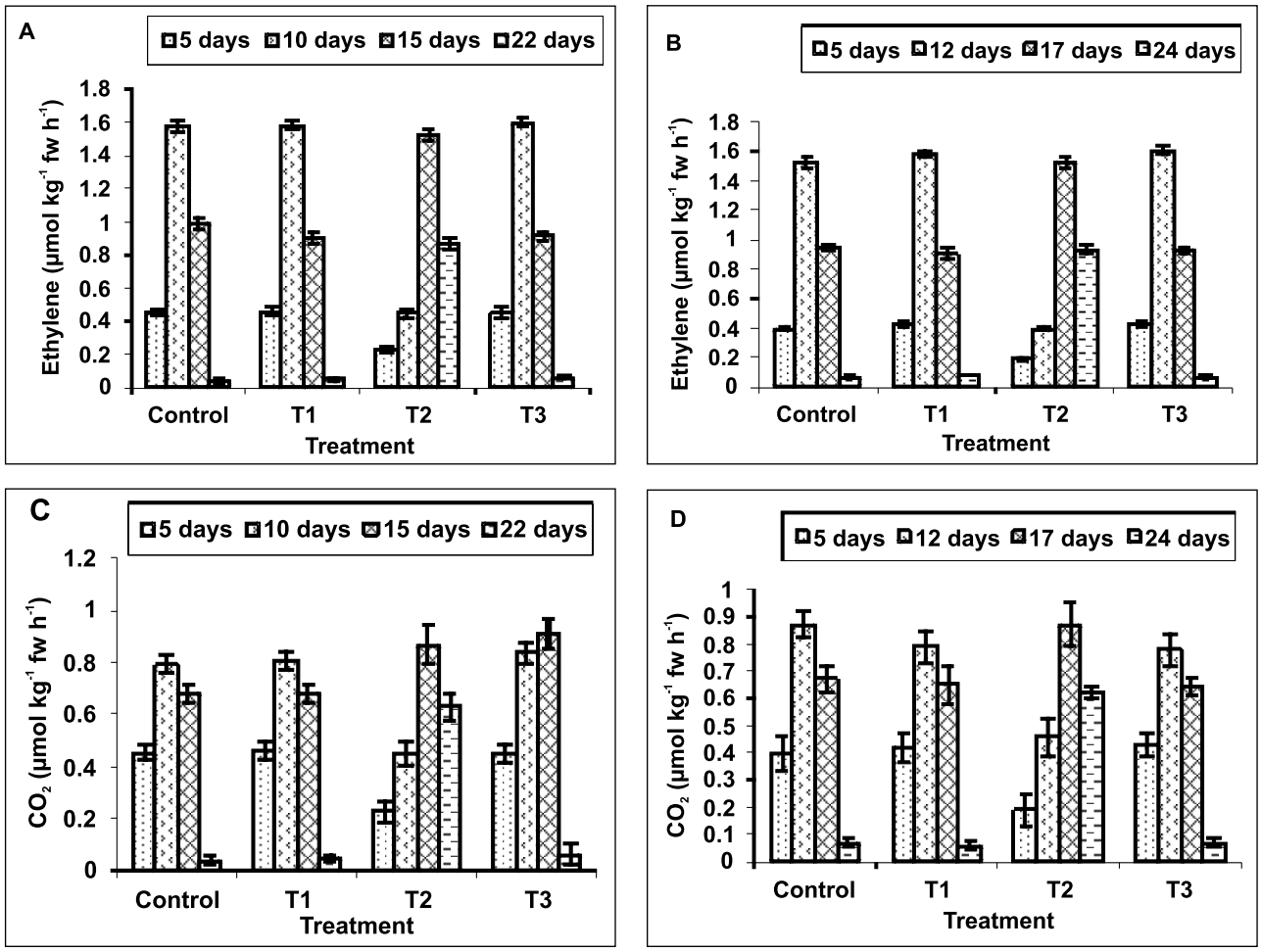

Fig. 1. Effect of postharvest SA treatments on ethylene production. (A) Pusa Rohini, (B) Pusa Gaurav and climacteric respiration, (C) Pusa Rohini, (D) Pusa Gaurav. LSD ($P \leq 0.05$). Vertical bars represents ± SE of means. Control (DDW); T_1 = 0.50 mM; T_2 = 0.75 mM; T_3 = 1.0 mM.

Thus, ripening and senescence triggered by ethylene and it stimulated the other ripening up regulating factors leading to early ripening of harvested fruits, and application of appropriate concentration of SA at early stages of fruit ripening resulted in delay and suppression of these activities.

The activities of ACS and ACO were found maximum at 10th day and 12th day in Pusa Rohini (Fig. 2A and 2B) and Pusa Gaurav (Fig. 4C and 4D), respectively in untreated/ control and other treatments. However, SA (0.75 mM) treated fruits showed reduced activities of ACS and ACO at early days of ripening, and found maximum at 15th day and 17th day in Pusa Rohini (Fig. 2A and 2B) and Pusa Gaurav (Fig. 4C and 4D), respectively thereafter activities declined in both the cultivars. Thus, ethylene production and activities of its biosynthetic enzymes delayed by five days in SA (0.75 mM) treated fruits with respect to untreated/control. Similar results were found in apple (Fan and He, 2; Mo *et al.*, 6) and kiwi fruit (Zhang *et al.*, 10), where SA reduced ethylene and activities of ACS as well as ACO. In banana, delayed fruit ripening by application of SA might be due to delayed and suppressed activities of ethylene biosynthetic enzymes as was reported by Srivastava and Dwivedi (9).

From above study it can be concluded that SA (0.75 mM) treatment delayed ethylene spurt and maintained the Ca, Cu and Zn contents with respect to untreated/ control in fruits of tomato cvs. Pusa Gaurav and Pusa Rohini enhancing their post-harvest shelf-life and maintaining nutritional quality.

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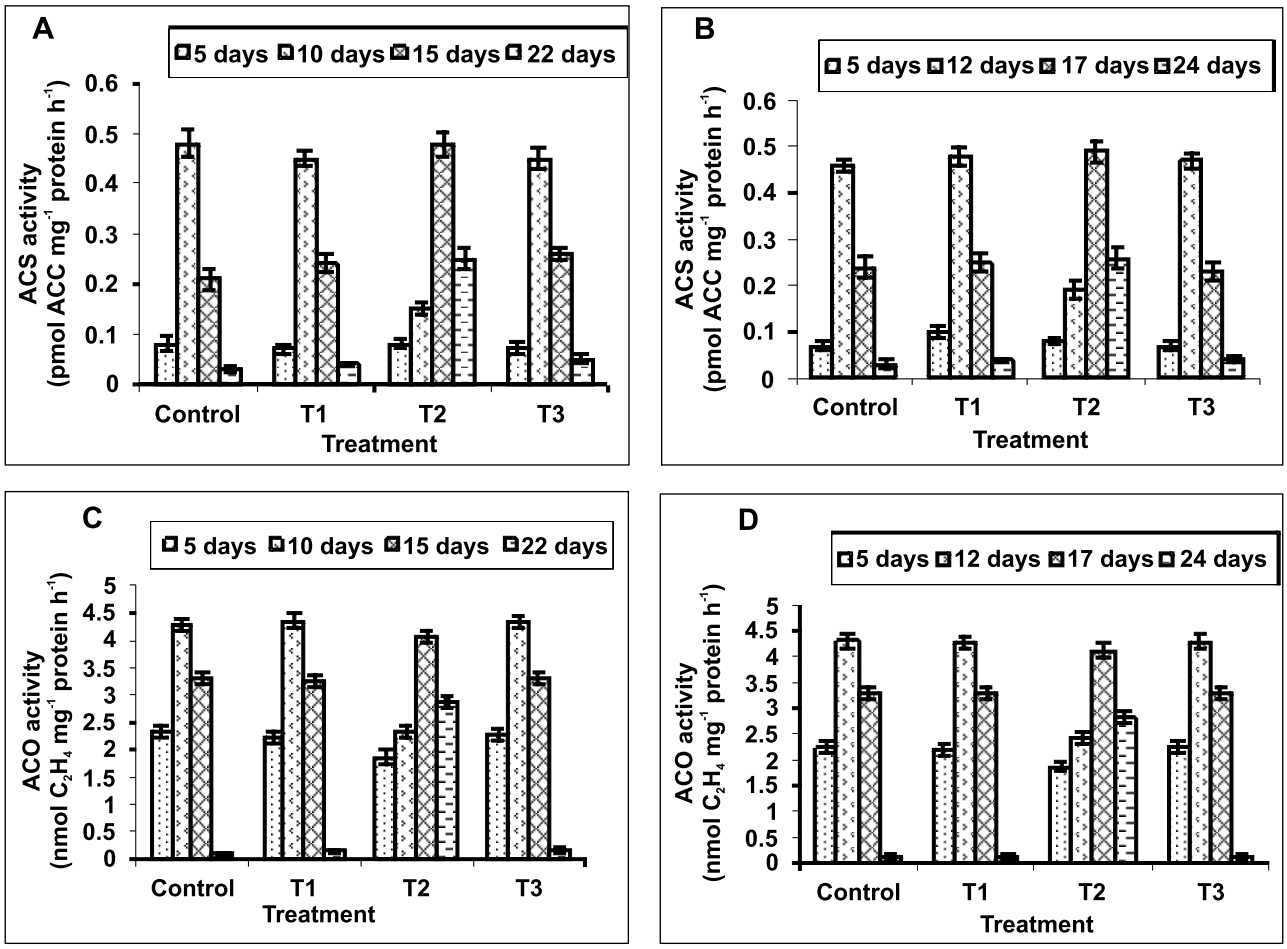

Fig. 2. Effects of postharvest SA treatments on ACS activity (A) Pusa Rohini (B) Pusa Gaurav and ACO activity (C) Pusa Rohini (D) Pusa Gaurav. LSD ($P \leq 0.05$). *Vertical bars* represents ± SE of means. Control (DDW); T_1 = 0.50 mM; T_2 = 0.75 mM; T_3 = 1.0 mM.

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