Indian Journal of Agricultural Sciences **86** (6): 727–31, June 2016/Article
https://doi.org/10.56093/ijas.v86i6.58835

Effect of pre-harvest application of salicylic acid on the postharvest fruit quality of the Amrapali mango (*Mangifera indica*)

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Received: 31 December 2015; Accepted: 5 January 2016

ABSTRACT

The shelf-life of mango (*Mangifera indica* L.) fruits is only 5 to 6 days under ambient conditions, which can be increased efficiently, if the rates of biological activities and/or changes are reduced by pre and/or post-harvest treatments. Hence, three different concentrations (75, 150 and 200 ppm) of salicylic acid (SA) were applied as pre-harvest treatments to Amrapali mango fruits, one week prior to their commercial harvest. Later the fruits were harvested and stored at ambient conditions (30±5 °C and 50±5 % RH). Among various concentrations of SA, the SA (200 ppm) was found to be most effective in delaying the ripening cum senescence processes through suppression of ethylene production rate (0.20 µl C_2H_4/kg/h) and helped in maintaining the post-harvest quality through better retention of soluble solid concentrates (SSC) (27.72 °B), titratable acidity (0.53 %), ascorbic acid (32.52 mg/100g) and total antioxidant content (11.85 µmol Trolox/g Fresh Weight) etc. The SA treatment was also found to effectively influence the pectin methylesterase activity (0.167 µmol acid/min) as well as the lipid peroxidation (2.26 nmol/g Fresh weight) during storage in order to extend the fruit shelf-life by 3 days compared to the control fruits.

Key words: Mango, MDA, PME, Post-harvest quality, Pre-harvest, Salicylic acid,

Mango (*Mangifera indica* L.) is an economically important fruit crop of India, known for its delicious taste, exceptional flavor and high nutritive value. Based on its popularity in the masses, wide adaptability, varietal diversity and attractive appearance, it is called as the 'King of fruits' in India (Litz 2009). Mangoes are good source of ascorbic acid, carotenoids, phenolic compounds and other dietary antioxidants that offer protection against several fatal diseases such as cancer (Joshipura *et al*. 2001, Talcott *et al*. 2005).

Being a climacteric fruit, it has little amounts of endogenous ethylene until maturity, which then rises dramatically leading to ripening of the fruit. The ripening can be delayed or slowed down either by removal of endogenous ethylene or through inhibition of its production using inhibitors. Off late, pre-harvest exogenous application of various synthetic chemicals, viz. cycloheximide, aminoethoxyvinyl glycine (AVG), silver nitrate, benzothiadiazole, sodium nitroprusside etc., were in vogue for inhibition of ethylene biosynthesis. But due to raising concerns of consumers regarding synthetic chemicals (Sharma *et al*. 2009), the research paradigm has shifted towards natural plant growth regulators such as gibberellic acid, putrescine etc. The discovery of new plant hormones and their ability to regulate all aspects of growth and development were defining moments in horticulture (Greene 2010). Some of them were tried and proven to be effective in extending shelf-life and reducing post-harvest losses either by delaying ripening and senescence or by preventing pathogenic infections in many fruit species (Lurie *et al*. 2010).

One such plant growth regulator compound is salicylic acid (SA) which plays an important role in regulating a variety of physiological processes in plants. The effect of SA on delaying fruit ripening, softening, and reducing disease resistance and reducing disease incidence were discussed by various researchers (Raskin 1992). Thus, in order to study the beneficial carryover effects of pre-harvest application of SA on the post-harvest quality during storage, the current experiment was designed with three different concentrations of SA applied one week before the commercial date of harvest.

MATERIALS AND METHODS

The present study was conducted at the experimental orchards of ICAR-Indian Agricultural Research Institute, New Delhi during the year 2013-14. Ten-year-old Amrapali mango trees were randomly selected for the pre-harvest application of different concentrations of ethylene bio-

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synthesis inhibitor salicylic acid (SA) @ 75, 150 and 200 ppm. The spray chemical was mixed with surfactant (1% Triton-X) for increasing the surface adhesiveness and applied on trees using a hand operated mist sprayer. The control fruits were sprayed with distilled water. The spraying was done one week (7 days) before the commercial harvest and it was done on all sides of the fruit as well as to the foliage surrounding the fruit. The fruits were harvested carefully along with stalk using secateurs and then transported to the laboratory. Later, the fruits were desapped, cleaned using tap water and were air dried under fan for 10-15 minutes. The fruits were then packed in ventilated CFB boxes and stored under ambient conditions (30±5 °C and 50±5 % RH). During storage, ethylene evolution, fruit quality, enzyme activity and membrane lipid peroxidation were evaluated at 3 day interval in terms of soluble solid concentrates (SSC), titratable acidity, ascorbic acid content, total antioxidant activity, pectin methylesterase activity, melandialdehyde content etc. The ethylene evolution rate was determined by headspace gas analysis using auto gas Hewlett Packard (HP) gas chromatograph (model 5890 Series II) equipped with a flame ionization detector (FID), Porapack-N 80/100 mesh packed stainless steel column and a HP integrator was used for determination of ethylene. The temperature of injector, column and detector were adjusted to 110°C, 60°C and 275°C and the flow rate of N_2, H_2 and air were maintained as 30, 30 and 300 ml/minute, respectively. The fruits were evaluated for soluble solid concentrates (SSC) and titratable acidity using the standard methods of Ranganna (1986). Ascorbic acid content was determined by 2, 6-dichlorophenol indophenol visual titration method described by Ranganna (1986) with some modifications. Total antioxidant capacity of the mango fruit pulp was determined using CUPRAC method, standardized by Apak *et al.* (2004) with slight modifications. Pectin methyl esterase (PME) activity in mango fruit pulp was measured following the method of Hagerman and Austin (1986) with minor modifications. The malondialdehyde (MDA) content in the mango fruits was measured according to the method standardized by Dhindsa *et al*. (1981) with little modifications. The results obtained were statistically analyzed using Factorial Completely Randomized Design (CRD) for interpretation of results through analysis of variance.

RESULTS AND DISCUSSION

In general, the ethylene evolution rate was low at harvest and it rose gradually with storage period and started decline after reaching the peak value during 3-6 days. Though the quantity of ethylene production was relatively low in mango fruits compared to other climacteric fruits, the rate of ethylene evolution increased rapidly in the control (untreated) fruits, which achieved the peak (3.84 µl C_2H_4/kg/h) on 3rd day of storage and declined slowly (1.49 µl C_2H_4/kg/h) towards the end of storage period (Fig 1). The ethylene peak was delayed to 6th day in fruits

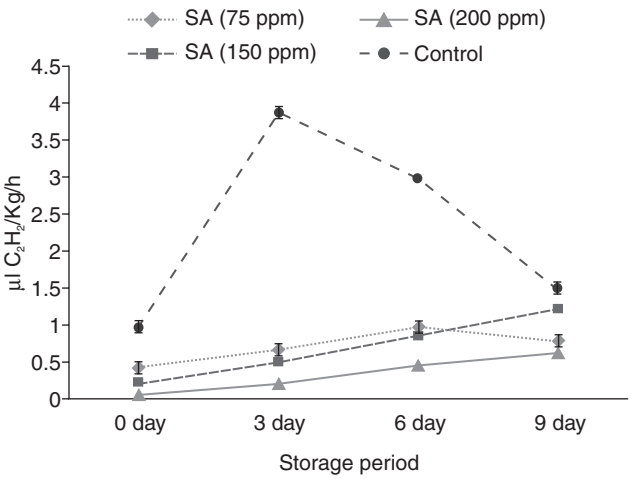

Fig 1 Effect of pre-harvest application of salicylic acid (SA) on ethylene evolution rate of the Amrapali mango fruits during storage.

treated with SA (75 ppm) and to 9th day in those treated with SA (150 and 200 ppm). Such suppression of ethylene production in SA treated mango fruit 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), apple (Shirzadeh and Kazemi 2012), plum (Luo *et al*. 2011) and strawberry (Babalar *et al*. 2007).

A rapid increase in the soluble solid concentrates (SSC) of the mango fruits was noticed from the day of harvest till the end of storage compared to the treated fruits (Fig 2). The untreated (control) fruits attained maximum SSC value (28.83 °B) on 6th day of storage and declined thereafter. Rapid and higher SSC in control fruits might be due to faster ripening and the hydrolysis of starch into simple sugars. The quicker decline may be due to higher respiration rate of untreated mango fruits than treated fruits, which

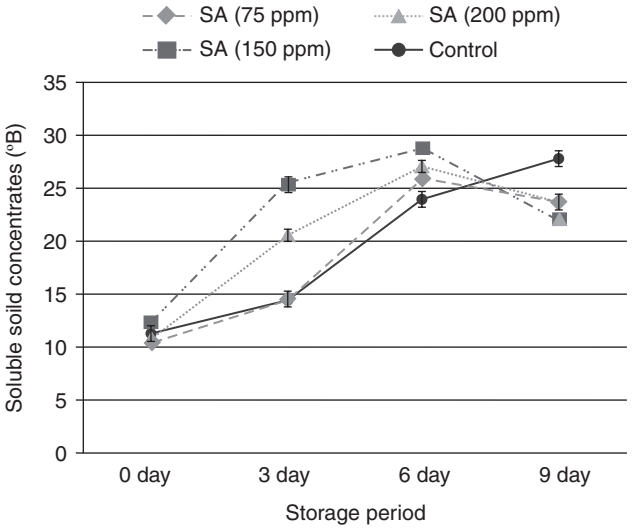

Fig 2 Influence of pre-harvest application of salicylic acid (SA) on soluble solid concentrates (°B) of the mango fruits during storage.

utilizes the simple sugars initially and the organic acids thereafter. A similar trend but with lower SSC value was observed in the mango fruits sprayed with different concentrations of the ethylene inhibitor SA. However, towards the end of storage life, highest TSS (27.72 °B) was recorded in SA (200 ppm) followed by SA (150 ppm) (23.65 °B) treated fruits (Fig 2). The delayed increase of TSS in SA treated fruits might be due to slower ripening in such fruits, caused by inhibition of ethylene biosynthesis (Fig 1). A delayed increase in TSS of SA treated fruits was reported in kiwi fruit (Kazemi *et al.* 2011a), apple (Kazemi *et al*. 2011b), peach (Khademi and Ershadi 2013) and persimmon (Khademi *et al*. 2012).

Titratable acidity abated with the advancement in storage period. The abating trend was rapid from the initial to 3rd day and, thereafter, it was slower (Fig 3). Similar findings have also been reported by Upadhyay *et al*. (1994). The reduction in acidity during storage after attainment of maturity and ripening might be due to the utilization of organic acids as a substrate for respiration next to the sugars. The fruits treated SA @ 200 ppm retained higher TA compared to other treatments or untreated mangos, which might be due to delayed ripening and senescence processes resulting in the reduction of acid oxidation.

The ascorbic acid content (AAC) of Amrapali mango fruits had increased gradually upto certain period and then decreased progressively with increase in storage period (Fig 4). However, in the fruits treated with SA (200 ppm), the AAC has showed a continual increasing trend towards the end of storage life. Among all the treatments, maximum AAC (32.52 mg/100g) was observed in mango fruits treated with SA @ 200 ppm followed by SA @ 150 ppm (25.76 mg/100g) at the end of storage life and minimum

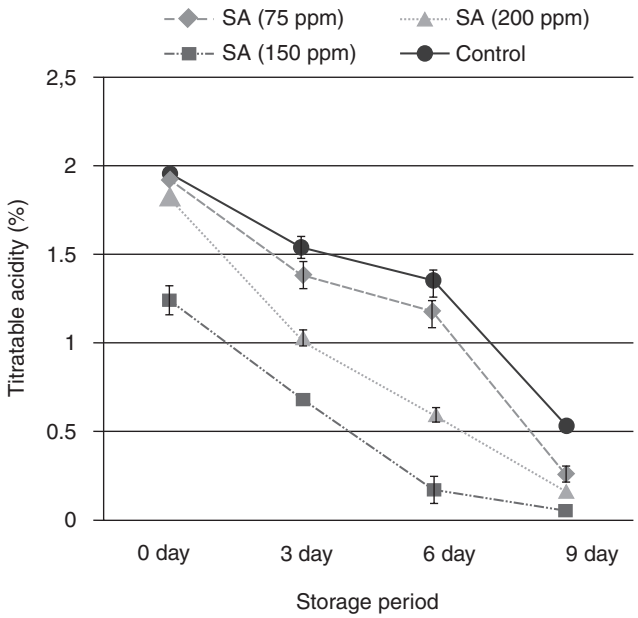

Fig 3 Influence of pre-harvest application of salicylic acid (SA) on the titratable acidity (%) of the mango fruits during storage.

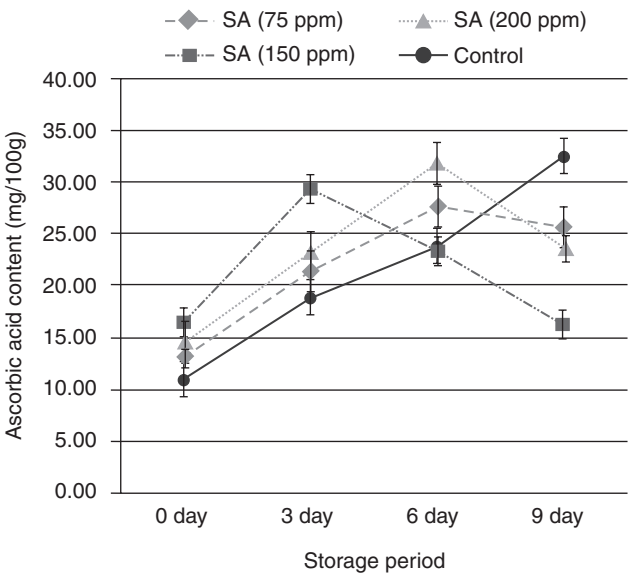

Fig 4 Effect of pre-harvest application of salicylic acid (SA) on the ascorbic acid content (mg/100g) of the mango fruits during storage.

(16.39 mg/100g) in the untreated (control) fruits. The increase in ascorbic acid content during ripening was attributed to the increase in lipid peroxidation considering that fruit ripening is an oxidative phenomenon requiring turnover of active oxygen species (Jimenez *et al*. 2002). Under such conditions, the antioxidant compounds including ascorbic acid usually get increased. The higher retention of ascorbic acid in the treated mango fruits might be due to delayed ripening process caused by suppressed ethylene production (Fig 1). Similar retention of ascorbic acid with SA treatment was also reported in apricot (Ardakani *et al*. 2013), kiwifruit (Zhu *et al*. 2010) and plum (Sharma 2014).

The total antioxidant activity (AOX) was significantly high in the mango fruits treated with SA @ 200 ppm compared to other treatments (Fig 5). The antioxidant activity was relatively low in the untreated fruits in comparison to the mango fruits sprayed with ethylene inhibitors, which might be due to retention of lower ascorbic content in the untreated (control) fruits towards the end of storage period and it is identified that vitamin C is an antioxidant compound protecting plants against oxidative damage (Noctor and Foyer 1998). Greater antioxidant activity in the SNP treated fruits might be due to their greater retention of ascorbic acid towards the end of storage period (Fig 4). Furthermore, the antioxidant capacity of mango fruit appears to be largely influenced by the polyphenol and flavonoid in addition to the ascorbic acid content. Highly significant linear correlations were observed between antioxidant capacity of the investigated mango fruit samples and their polyphenol and flavonoid contents (Ma *et al*. 2011). Furthermore, the antioxidant activity decreased progressively after increasing to certain level towards the end of storage period. This reduction in antioxidant capacity can be related with the progressive

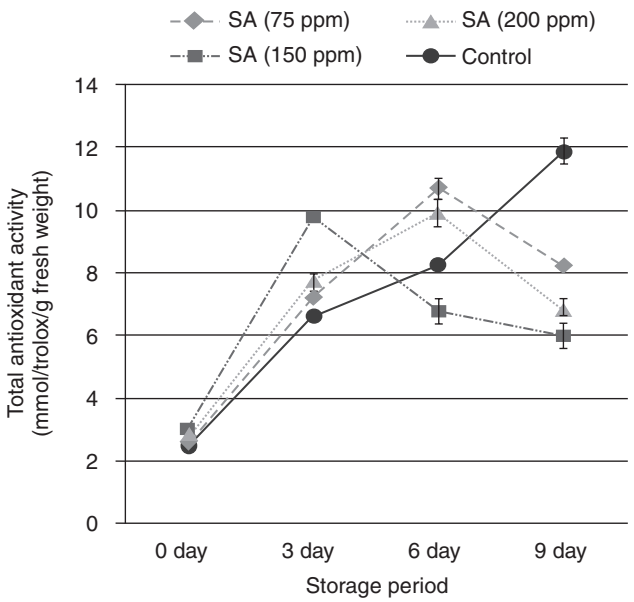

Fig 5 Effect of pre-harvest application of salicylic acid (SA) on the total antioxidant activity (µmol Trolox/g fresh weight) of the mango fruits during storage.

decrease of ascorbic content (Fig 4). Similar findings on progressive decline in total antioxidant activity have also been in banana (Fernando *et al.* 2014) and plum (Sharma *et al.* 2012).

The PME activity in the mango fruits has showed an initial increase till 3rd day from the day of harvest in the untreated fruits but it has decreased slowly towards the 9th day of storage. However, the PME activity has shown increasing trend till 6th day of storage and then decreased thereafter in the treated fruits. Interestingly, the PME activity was observed to be increasing constantly till the end of storage period in the fruits treated with SA (200 ppm). Among all, the highest PME activity (0.228 µmol acid/min) was observed in the untreated fruits on the 3rd day of storage non-significantly followed by SA (150 ppm) on 6th day of storage (0.208 µmol acid/min), while the lowest PME activity (0.092 µmol acid/min) was observed in SA (200 ppm) treated fruits. These results are in line with the reports of Selvaraj and Kumar (1989) who reported that the PME activity increased until half-ripe stage and declined thereafter in Carabao mango fruits. Higher PME activity in untreated fruits may be due to rapid ripening in fruits during which the cell wall polymers such as pectin, cellulose and hemicellulose undergo substantial transformation and solubilisation resulting in cell wall disintegration and fruit softening (Yashoda 2003). Furthermore, it has also been demonstrated that SA-treatment decreases ethylene production and it inhibits cell wall and membrane degrading enzymes such as polygalacturonase (PG), lipoxygenase (LOX), cellulase and pectinemethylesterase (PME) leading to decreasing the fruit softening rate (Srivastava and Dwivedi 2000, Zhang 2003).

A notable increase in malondialdehyde (MDA) content was observed in Amrapali mango fruits, suggesting that peroxidation might have taken place during storage of fruits. There were significant differences in MDA content of treated and control fruits. The MDA content in the mango fruits increased constantly irrespective of the treatment towards the end of storage period. However, irrespective of the storage period, the MDA content was highest (6.38 nmol/g Fresh weight) in the untreated (control) fruits and lowest MDA (0.21 nmol/g FW) was observed in SA (200 ppm) treated mango fruits on the day of harvest. Higher MDA content in untreated mango fruits might be due to the cell membrane injury caused by the reactive oxygen species, enzymes of lipid peroxidation which further increase the deterioration and senescence rate in fruits (Luo *et al*. 2011). The reduced MDA content of SA treated mango fruits might be due to delayed ethylene peaks, lower free radical production and maintenance of firmness by the fruits that could inhibit ripening and tissue deterioration in mango fruits during storage (Luo *et al*. 2011). Similar patterns of MDA formation was observed in kiwi fruit (Zhu *et al*. 2010), plum (Sharma and Sharma 2014).

Application of salicylic acid as a pre-harvest spray, one week prior to harvest could effectively modulate the ripening behavior of the Amrapali mango fruits during storage at ambient conditions (30±5 °C and 50±5 % RH). Among various concentrations (75, 150 and 200 ppm) of SA applied, the SA (200 ppm) was found to be effective in delaying the ripening cum senescence processes through suppression of ethylene production rate and helped in maintaining the postharvest quality through better retention of soluble solid concentrates (SSC), titratable acidity, ascorbic acid and total antioxidant content etc. Also, this SA treatment influenced the pectin methylesterase activity as well as the lipid peroxidation during storage in order to extend the fruit shelf life by 3 days.

ACKNOWLEDEMENT

The authors thank the Department of Science and Technology, Government of India, for providing financial support in the form of an INSPIRE Fellowship granted to Dr Vijay Rakesh Reddy for pursuance of Ph D research programme at the ICAR-Indian Agricultural Research Institute, New Delhi, India.

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