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Impact of 1-Methylcyclopropene and Salicylic Acid Treatments on Quality Characteristics of "Keitt" Mangos during Storage and Shelf Life

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Abstract: This investigation was carried out during 2014 and 2015 seasons to evaluate the effect of 1-MCP (1-Methylcyclopropene) and SA (salicylic acid) on Keitt mangos storability and shelf life. Both materials were used in two concentrations applied to mature green fruits before storage at 12°C, 90-95 % RH for 28 days followed by storage at 20°C, 90-95 % RH for 8 days. Quality attributes of Keitt mango fruits were maintained by using 1-MCP and SA to a better extent compared with untreated ones. They suppressed the increase in decay percentage and respiration rate. Fruit appearance and colour changes were significantly better in fruits treated by 1-MCP at 1 µL L^{-1}. 1-MCP treatment had the potential to slow down softening and other changes that occurred in fruit composition during ripening such as; TSS, acidity, total phenols and ascorbic acid.

Key words: Mango · Keitt · 1-MCP · Salicylic acid · Cold storage · Shelf life

INTRODUCTION

Mangos (*Mangifera indica* L.) are one of the most popular fruits in Egypt and are widely distributed all over the world. Mangos are climacteric fruits thus ethylene stimulates their ripening, affects many physiological processes and accelerates their senescence and deterioration [1].

1-Methylcyclopropene (1-MCP) is an inhibitor of ethylene action. It is used to delay fruit ripening and senescence. It irreversibly binds to ethylene receptors in plant tissues, blocking the binding of ethylene [2]. The physiological responses of climacteric fruits to 1-MCP include altering ethylene production and respiration, delaying colour changes and softening [3]. 1-MCP was reported to delay fruit softening, climacteric peak, decrease rate of respiration and weight loss during mango fruits storage [4]. On the other contrary Osuna-Garcia *et al*. [5] and Hofman *et al*. [6] found that 1-MCP had no effect or even in some cases, increased the incidence of decay. The effective 1-MCP concentration for prolonging the shelf life of mangos was reported to be between 1 and 10 µL L^{-1} [7].

Salicylic acid (SA) is a plant hormone inhibiting ethylene biosynthesis and thus delaying the senescence [8]. Charles and Roger [9] and Leslie and Romani [10] indicated that salicylic acid inhibited ethylene formation from ACC (1-aminocyclopropane-1-carboxylic acid) by suppressing ACO (1-aminocyclopropane-1-carboxylic acid oxidase) activity [11]. Postharvest or preharvest salicylic acid treatment was found to be effective in delaying the ripening and senescence processes through suppression of ethylene production rate and maintaining the post-harvest quality [12]. Luo *et al*. [13] found that SA treatment alleviated postharvest decay of plum fruit. Also exogenous supplied SA has been reported to delay the ripening of kiwifruit [14], apple [15], peach [16], persimmon [17] and banana [18].

The objectives of this study were to assess the impact of two concentrations of 1-MCP and SA on Keitt mangos to delay fruit ripening, senescence and maintain quality attributes during cold storage and shelf life.

MATERIAL AND METHODS

Keitt mangos were harvested manually at the commercial maturity stage [19] from a private orchard in El-Khatatba region, Egypt. The harvested fruits were almost similar in size and skin colour and free of obvious mechanical damage and pathological defects. Fruits were washed by tap water, then soaked in one of following; 1 or 2 µL L^{-1} 1-MCP (0.14% formulation, SmartFresh, AgroFresh, Inc.), 1 or 2 mmol L^{-1} SA, as well as distilled water (control) for 5 min, then the fruits were left to dry at room temperature. After treatments applications fruits were packed in carton boxes and stored at 12°C and 90-95 % relative humidity (RH) for 28 days followed by storage at 20°C and 90-95 % RH for 8 days. After 0, 7, 14,

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21 and 28 days of storage at 12°C and after 4 and 8 days of storage at 20°C, 3 fruits from each replicate of each treatment were sampled for analysis.

Fruits that showed any signs of decay during storage were counted and discarded. Decay percentage was calculated as number of discarded fruits / total number of fruits × 100. Fruit general appearance was evaluated visually using the following visual score as described by Mitcham *et al*. [20]; on a scale 1 to 9 with 1= unacceptable, 3= poor, 5= fair, 7= good and 9= excellent. Instrumental flesh colour was measured in the CIE $L^*a^*b^*$ on two paired cheeks of each fruit objectively using a Minolta CR-400 chroma meter (Minolta, Osaka, Japan) [20].

Fruit weight loss percentage was calculated using the following equation; (Fruit initial weight – Fruit weight at each sampling date) / Fruit initial weight × 100. Fruit firmness was determined according to Mitcham *et al*. [20] by a fruit pressure tester (8 mm diameter probe) on pared surfaces from opposite sides of each fruit, data was presented as lbf. Respiration rate was measured by analyzing carbon dioxide using gas chromatography (Model 1450-Servomex 1400) [21], Fruits were incubated in 4-liter airtight glass jars for 24 hr at the same experimental conditions, respiration rate was expressed as concentration of CO_2 ml / kg / hr.

Total soluble solids % were assessed by using a digital refractometer using drops of the fruit juice. Total acidity was measured by titrating 10 ml of the extracted juice against 0.1 N of NaOH using phenol phathalin indicators [22] and expressed as percentage of citric acid. Total phenols as mg gallic acid per 100 g FW were determined colourmetrically using Folin Denis reaction method at 765 nm according to Swain and Hillis [23]. Ascorbic acid was determined using titration method by 2,6 dicholorophenol-indophenol solution, results were expressed as mg ascorbic acid per 100 g FW [24].

A completely randomized block design was followed, the treatment means were compared using the method of LSD at the 5% level of significance [25].

RESULTS AND DISCUSSION

Decay Percentage: Data in Table 1 show the effect of 1-MCP and SA treatments on decay % in both seasons. Decay increased continuously with storage time during both seasons. The differences between treatments were significant in both seasons, 1-MCP treatments recorded the lowest percentages of decay in both seasons compared with the control, especially the treatment of 1 µL L^{-1} 1-MCP that maintained the lowest significant levels after 8 days of shelf life at 20°C in both seasons. The obtained data are similar to those presented by Jiang and Joyce [7] and Bal and Celik [14], they reported that, 1-MCP and SA slowed the biological processes and many disorders. Also, Zhi-qiang [26] found that, 1-MCP was very effective in decreasing decay as it substantially reduced the incidence and severity of many physiological disorders and storage rots.

General Appearance: Table 2 presents the effect of 1-MCP and SA treatments on fruits general appearance. It decreased sharply during shelf life, treated fruits quality score recorded higher values in both seasons compared with the control, all treated fruits by 1-MCP were more acceptable significantly after storage and shelf life periods in both seasons.

Table 1: Effect of 1-MCP and SA treatments on fruit decay (%) in 2014, 2015 seasons.

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	0.00	0.00	0.00	1.48	3.70	1.04	5.92	22.22	14.07
2µL L^{-1} 1-MCP	0.00	0.00	0.00	1.48	5.93	1.48	9.63	27.41	18.52
1mmol L^{-1} SA	0.00	0.00	2.22	4.44	7.41	2.81	23.70	33.33	28.52
2mmol L^{-1} SA	0.00	0.00	2.22	2.96	7.34	2.50	21.48	30.37	25.93
Control	0.00	0.00	2.22	11.11	16.30	5.93	26.67	39.26	32.96
Mean	0.00	0.00	1.33	4.29	8.13		17.48	30.52	
L.S.D $^{0.05}$	(A) = 0.96, (B) = 0.96, (A×B) = 2.14						(A) = 4.02, (B) = 2.54, (A×B) = 5.68		
				Second season					
1µL L^{-1} 1-MCP	0.00	0.00	0.00	1.48	4.44	1.18	15.56	20.00	17.78
2µL L^{-1} 1-MCP	0.00	0.00	0.00	1.48	5.93	1.48	17.78	24.44	21.11
1mmol L^{-1} SA	0.00	0.00	1.48	5.18	8.15	2.96	26.67	34.07	30.37
2mmol L^{-1} SA	0.00	0.00	2.22	3.70	7.34	2.65	20.00	31.85	25.93
Control	0.00	0.00	2.22	11.85	16.30	6.07	26.67	40.74	33.70
Mean	0.00	0.00	1.18	4.74	8.43		21.33	30.22	
L.S.D $^{0.05}$	(A) = 0.98, (B) = 0.98, (A×B) = 2.20						(A) = 3.12, (B) = 1.97, (A×B) = 4.41		

Table 2: Effect of 1-MCP and SA treatments on fruit general appearance[z] in 2014, 2015 seasons

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	9.00	9.00	9.00	9.00	8.85	8.97	7.73	7.00	7.37
2µL L^{-1} 1-MCP	9.00	9.00	9.00	9.00	8.70	8.94	7.51	6.92	7.22
1mmol L^{-1} SA	9.00	9.00	8.85	8.40	7.37	8.52	6.63	5.89	6.26
2mmol L^{-1} SA	9.00	9.00	9.00	8.70	8.26	8.79	7.37	6.11	6.74
Control	9.00	9.00	8.18	7.52	6.92	8.12	4.99	4.26	4.62
Mean	9.00	9.00	8.81	8.52	8.02		6.85	6.03	
L.S.D $^{0.05}$	(A) = 0.23, (B) = 0.23, (A×B) = 0.52						(A) = 0.30, (B) = 0.19, (A×B) = 0.42		
				Second season					
1µL L^{-1} 1-MCP	9.00	9.00	9.00	9.00	8.18	8.84	7.96	7.22	7.59
2µL L^{-1} 1-MCP	9.00	9.00	9.00	9.00	7.96	8.79	7.73	6.92	7.33
1mmol L^{-1} SA	9.00	9.00	8.92	7.96	7.73	8.52	5.52	4.77	5.15
2mmol L^{-1} SA	9.00	9.00	9.00	8.92	7.81	8.75	6.62	5.52	6.07
Control	9.00	9.00	8.11	7.44	6.48	8.00	4.63	3.96	4.29
Mean	9.00	9.00	8.81	8.46	7.63		6.49	5.68	
L.S.D $^{0.05}$	(A) = 0.11, (B) = 0.11, (A×B) = 0.25						(A) = 0.47, (B) = 0.30, (A×B) = 0.67		

[z] General appearance was evaluated visually on a scale, 1= unacceptable, 3= poor, 5= fair, 7= good and 9= excellent

Table 3: Effect of 1-MCP and SA treatments on fruit flesh L* value in 2014, 2015 seasons

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	66.58	65.58	65.24	64.24	63.51	65.03	59.18	55.84	57.51
2µL L^{-1} 1-MCP	66.58	64.91	64.51	63.51	62.18	64.34	57.84	54.18	56.01
1mmol L^{-1} SA	66.58	63.91	63.64	61.64	58.31	62.82	57.98	51.31	54.64
2mmol L^{-1} SA	66.58	63.51	63.14	61.54	59.38	62.83	58.38	52.71	55.54
Control	66.58	62.58	61.24	58.28	56.28	60.99	54.28	52.28	53.28
Mean	66.58	64.10	63.56	61.84	59.93		57.53	53.26	
L.S.D $^{0.05}$	(A) = 0.92, (B) = 0.92, (A×B) = 2.05						(A) = 1.81, (B) = 1.14, (A×B) = 2.56		
				Second season					
1µL L^{-1} 1-MCP	67.85	62.36	61.03	60.70	56.70	61.73	52.36	46.93	49.65
2µL L^{-1} 1-MCP	67.85	62.00	61.00	59.33	56.66	61.37	50.00	46.66	48.33
1mmol L^{-1} SA	67.85	62.03	61.03	58.03	53.37	60.46	48.03	46.03	47.03
2mmol L^{-1} SA	67.85	61.90	60.90	58.23	55.90	60.96	47.23	46.63	46.93
Control	67.85	62.10	61.10	55.10	50.43	59.31	44.10	43.43	43.76
Mean	67.85	62.08	61.01	58.28	54.61		48.34	45.94	
L.S.D $^{0.05}$	(A) = 0.93, (B) = 0.93, (A×B) = 2.07						(A) = 1.61, (B) = 1.02, (A×B) = 2.28		

Colour Measurement: L^* value measures colour lightness (higher values are lighter), a^* indicates colour direction with $+a^*$ is the red direction and $-a^*$ is the green direction and b^* indicates colour direction with $+b^*$ is the yellow direction and $-b^*$ is the blue direction. L^* flesh value decreased with time as shown in Table 3 in both seasons. 1 µL L^{-1} 1-MCP treatment attained the brightest colour during storage at 12°C and shelf life at 20°C.

Values of b^* flesh decreased with time as shown in Table 4 in both seasons. 1, 2 µL L^{-1} 1-MCP and 2 mmol L^{-1} SA treatments showed the highest values during storage at 12°C and shelf life at 20°C. In addition, L^* and a^* values of peel revealed the same trend of fruit colour changes (data are not shown). The obtained data revealed that 1-MCP and SA delayed discolouration of flesh and degradation of peel colour, in accordance with data obtained by Watkins [3] that attributed the effects of 1-MCP to inhibition of mango discolouration.

Weight Loss %: Table 5 show that, weight loss % increased continuously under all circumstances, in general; untreated fruits retained its weight compared with the other fruits, but anyway differences between untreated fruits and fruits treated by different

Table 4: Effect of 1-MCP and SA treatments on fruit flesh b* value in 2014, 2015 seasons.

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	63.34	62.84	61.48	57.12	55.12	59.98	52.79	51.12	51.95
2µL L^{-1} 1-MCP	63.34	62.83	61.94	55.89	54.89	59.78	52.89	50.89	51.89
1mmol L^{-1} SA	63.34	62.82	61.74	53.71	53.37	59.00	51.71	50.37	51.04
2mmol L^{-1} SA	63.34	62.81	61.67	55.30	55.30	59.68	51.30	50.63	50.97
Control	63.34	62.63	61.41	55.39	52.06	58.97	50.06	49.06	49.56
Mean	63.34	62.78	61.65	55.48	54.15		51.75	50.42	
L.S.D $^{0.05}$	(A) = 0.58, (B) = 0.58, (A×B) = 1.30						(A) = 1.54, (B) = 0.97, (A×B) = 2.18		
				Second season					
1µL L^{-1} 1-MCP	65.84	61.43	60.90	57.18	54.52	59.97	52.52	51.38	51.95
2µL L^{-1} 1-MCP	65.84	61.41	60.93	57.05	53.72	59.79	51.38	51.05	51.22
1mmol L^{-1} SA	65.84	61.54	60.96	56.91	52.55	59.56	51.21	49.55	50.38
2mmol L^{-1} SA	65.84	61.40	61.06	57.34	54.68	60.07	53.34	50.01	51.68
Control	65.84	61.08	59.80	53.81	52.81	58.67	49.48	48.14	48.81
Mean	65.84	61.37	60.73	56.46	53.65		51.59	50.03	
L.S.D $^{0.05}$	(A) = 0.91, (B) = 0.91, (A×B) = 2.05						(A) = 1.25, (B) = 0.79, (A×B) = 1.77		

Table 5: Effect of 1-MCP and SA treatments on fruit weight loss (%) in 2014, 2015 seasons.

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	0.00	0.97	1.83	2.51	3.06	1.67	3.80	4.33	4.06
2µL L^{-1} 1-MCP	0.00	0.90	1.65	2.25	3.09	1.58	3.92	4.42	4.17
1mmol L^{-1} SA	0.00	1.21	2.14	2.72	3.63	1.94	4.38	5.02	4.70
2mmol L^{-1} SA	0.00	1.16	1.89	2.32	3.32	1.74	3.92	4.60	4.26
Control	0.00	0.98	1.61	2.24	2.74	1.51	3.69	4.37	4.03
Mean	0.00	1.04	1.82	2.41	3.17		3.94	4.54	
L.S.D $^{0.05}$	(A) = 0.03, (B) = 0.03, (A×B) = 0.07						(A) = 0.20, (B) = 0.13, (A×B) = 0.29		
				Second season					
1µL L^{-1} 1-MCP	0.00	1.01	1.90	2.60	3.18	1.74	3.74	5.50	4.62
2µL L^{-1} 1-MCP	0.00	0.93	1.72	2.35	3.22	1.64	3.90	5.44	4.67
1mmol L^{-1} SA	0.00	1.32	2.34	2.97	3.96	2.12	4.47	5.63	5.05
2mmol L^{-1} SA	0.00	1.25	2.04	2.51	3.59	1.88	4.02	5.45	4.74
Control	0.00	1.10	1.80	2.50	3.07	1.69	3.69	4.61	4.15
Mean	0.00	1.12	1.95	2.58	3.40		3.96	5.32	
L.S.D $^{0.05}$	(A) = 0.08, (B) = 0.08, (A×B) = 0.19						(A) = 0.72, (B) = 0.45, (A×B) = 1.01		

concentrations of 1-MCP were insignificant by the end shelf life at 20°C, Hofman *et al*. [6] reported similar findings. On the other hand, it was previously shown that the weight loss % of fruits significantly decreased with SA treatment in comparison with control treatment during storage [15]. Also, Zheng and Zhang [27] reported that SA caused reductions in rates of weight loss of fruit by closing stomata. Woods [28] showed that the weight loss of fruits throughout storage period could be due to the water exchange between the internal and external atmosphere, the transpiration rate was accelerated by time elapse due to cellular breakdown.

Firmness: Firmness decreased gradually during cold storage and shelf life. All treated fruits were significantly firmer than the untreated fruits (Table 6). Also fruits treated with 1 and 2 µL L^{-1} 1-MCP were firmer compared with the other fruits. Kazemi *et al*. [29] reported that the effect of SA on the reduction of fruit softening can be attributed to ACO activity inhibition and decreasing ACC conversion to ethylene. In accordance with this hypothesis, the exogenously applied SA maintained higher levels of fruit firmness and these levels led to extend shelf life. There was no significant concentration effect on firmness retention among 1-MCP treatments (0.5-10.0 µL L^{-1}) [7]. In general, 1-MCP effectively delayed ripening (characterized by fruit softening) compared to the untreated control and this was in accordance with previous findings [30-31].

Table 6: Effect of 1-MCP and SA treatments on fruit firmness (lbf) in 2014, 2015 seasons

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	15.50	13.80	11.40	10.37	8.67	11.95	7.47	6.77	7.12
2µL L^{-1} 1-MCP	15.50	13.73	11.67	10.33	8.50	11.95	7.33	6.60	6.97
1mmol L^{-1} SA	15.50	13.60	11.37	10.17	7.77	11.68	6.83	5.07	5.95
2mmol L^{-1} SA	15.50	13.77	11.63	9.83	7.83	11.71	6.93	5.93	6.43
Control	15.50	13.27	11.00	8.40	7.47	11.13	5.93	5.30	5.62
Mean	15.50	13.63	11.41	9.82	8.05		6.90	5.93	
L.S.D $^{0.05}$	(A) = 0.25, (B) = 0.25, (A×B) = 0.57						(A) = 0.47, (B) = 0.29, (A×B) = 0.66		
				Second season					
1µL L^{-1} 1-MCP	15.83	13.83	11.43	10.40	8.70	12.04	7.67	6.97	7.32
2µL L^{-1} 1-MCP	15.83	13.63	11.27	10.33	8.50	11.91	7.27	6.93	7.10
1mmol L^{-1} SA	15.83	13.67	11.37	10.30	7.77	11.79	6.87	5.57	6.22
2mmol L^{-1} SA	15.83	13.83	11.40	9.87	7.83	11.75	6.97	6.20	6.58
Control	15.83	13.23	10.63	8.37	7.43	11.10	5.90	4.97	5.44
Mean	15.83	13.64	11.22	9.85	8.05		6.93	6.13	
L.S.D $^{0.05}$	(A) = 0.31, (B) = 0.31, (A×B) = 0.71						(A) = 0.44, (B) = 0.27, (A×B) = 0.62		

Table 7: Effect of 1-MCP and SA treatments on fruit respiration rate (ml CO_2/Kg/hr) in 2014, 2015 seasons

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	10.48	7.65	11.74	22.97	29.68	16.50	29.88	33.96	31.92
2µL L^{-1} 1-MCP	10.48	9.47	10.23	20.75	31.03	16.39	33.19	37.66	35.43
1mmol L^{-1} SA	10.48	9.73	12.30	21.50	31.63	17.13	35.29	45.21	40.25
2mmol L^{-1} SA	10.48	8.22	11.97	23.55	31.55	17.16	32.69	47.59	40.14
Control	10.48	8.15	14.08	27.71	31.75	18.43	33.75	49.53	41.64
Mean	10.48	8.64	12.06	23.30	31.13		32.96	42.79	
L.S.D $^{0.05}$	(A) = 1.05, (B) = 1.05, (A×B) = 2.34						(A) = 1.72, (B) = 1.09, (A×B) = 2.43		
				Second season					
1µL L^{-1} 1-MCP	10.81	7.76	11.42	22.67	29.42	16.42	30.21	34.30	32.25
2µL L^{-1} 1-MCP	10.81	9.65	10.48	20.75	30.70	16.48	32.86	37.66	35.26
1mmol L^{-1} SA	10.81	9.74	12.53	22.13	31.64	17.37	35.62	42.88	39.25
2mmol L^{-1} SA	10.81	8.48	11.98	24.41	30.67	17.27	33.69	42.92	38.31
Control	10.81	8.77	14.38	27.83	31.28	18.61	34.75	44.87	39.81
Mean	10.81	8.88	12.16	23.56	30.74		33.43	40.52	
L.S.D $^{0.05}$	(A) = 0.80, (B) = 0.80, (A×B) = 1.79						(A) = 1.81, (B) = 1.14, (A×B) = 2.56		

Fruit Respiration Rate: Data in Table 7 show that, respiration rate increased significantly by time elapse especially during shelf life. 1-MCP and SA treatments resulted in significantly lower rates compared with the control during cold storage in both seasons, whereas during shelf life at 20°C 1-MCP treatments showed the lowest significant rates. Zheng and Zhang [27] reported that SA caused reductions in respiration rates by closing stomata. Charles and Roger [9] and Watkins [3] reported that SA acid and 1-MCP inhibited ethylene formation from ACC and decrease respiration rate.

TSS: Table 8 presents the impact of different concentrations of 1-MCP and SA on TSS %. Fruits treated with 1 µL L^{-1} 1-MCP showed the lowest TSS percentages compared with untreated fruits which showed the highest values during cold storage and shelf life in both seasons. The increase in total soluble solids content during storage was probably due to the concentrating the juice as a result of dehydration and hydrolysis of polysaccharides [31]. The effect of 1-MCP and SA can be attributed to lowering levels of the respiration rate, ethylene production and delaying the ripening process. This seems similar to previous findings [29-30].

Table 8: Effect of 1-MCP and SA treatments on fruit TSS % in 2014, 2015 seasons.

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	13.87	13.97	14.13	14.77	15.30	14.41	15.73	17.56	16.65
2µL L^{-1} 1-MCP	13.87	13.90	14.20	15.03	15.37	14.47	16.19	17.67	16.93
1mmol L^{-1} SA	13.87	14.97	15.03	16.37	16.47	15.34	16.77	17.87	17.32
2mmol L^{-1} SA	13.87	14.93	15.62	16.10	16.20	15.34	16.30	17.97	17.13
Control	13.87	15.03	15.43	16.10	16.93	15.47	17.39	18.19	17.79
Mean	13.87	14.56	14.88	15.67	16.05		16.48	17.85	
L.S.D $^{0.05}$	(A) = 0.35, (B) = 0.35, (A×B) = 0.79						(A) = 0.26, (B) = 0.16, (A×B) = 0.36		
				Second season					
1µL L^{-1} 1-MCP	13.72	13.94	14.32	15.05	15.52	14.51	15.57	16.77	16.17
2µL L^{-1} 1-MCP	13.72	13.76	14.35	15.74	15.94	14.70	16.37	16.83	16.60
1mmol L^{-1} SA	13.72	14.22	15.35	15.44	16.09	14.96	16.53	16.97	16.75
2mmol L^{-1} SA	13.72	14.61	15.26	15.62	15.73	14.99	16.87	16.91	16.89
Control	13.72	14.44	15.92	16.03	16.30	15.28	17.07	17.53	17.30
Mean	13.72	14.19	15.04	15.57	15.91		16.48	17.00	
L.S.D $^{0.05}$	(A) = 0.49, (B) = 0.49, (A×B) = 1.09						(A) = 0.66, (B) = 0.40, (A×B) = 0.89		

Table 9: Effect of 1-MCP and SA treatments on fruit acidity % in 2014, 2015 seasons

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	1.472	0.747	0.739	0.520	0.478	0.791	0.435	0.345	0.390
2µL L^{-1} 1-MCP	1.472	0.650	0.533	0.515	0.448	0.724	0.415	0.341	0.378
1mmol L^{-1} SA	1.472	0.600	0.527	0.469	0.395	0.693	0.347	0.311	0.329
2mmol L^{-1} SA	1.472	0.646	0.632	0.511	0.427	0.738	0.408	0.337	0.373
Control	1.472	0.576	0.439	0.405	0.384	0.655	0.315	0.291	0.303
Mean	1.472	0.644	0.574	0.484	0.426		0.384	0.325	
L.S.D $^{0.05}$	(A) = 0.065, (B) = 0.065, (A×B) = 0.146						(A) = 0.038, (B) = 0.024, (A×B) = 0.054		
				Second season					
1µL L^{-1} 1-MCP	1.609	0.780	0.662	0.546	0.492	0.818	0.418	0.348	0.383
2µL L^{-1} 1-MCP	1.609	0.766	0.607	0.541	0.485	0.802	0.385	0.321	0.353
1mmol L^{-1} SA	1.609	0.570	0.506	0.473	0.397	0.711	0.351	0.294	0.322
2mmol L^{-1} SA	1.609	0.625	0.615	0.504	0.437	0.758	0.416	0.317	0.367
Control	1.609	0.571	0.491	0.422	0.395	0.698	0.365	0.289	0.327
Mean	1.609	0.662	0.576	0.497	0.441		0.387	0.314	
L.S.D $^{0.05}$	(A) = 0.066, (B) = 0.066, (A×B) = 0.148						(A) = 0.066, (B) = 0.042, (A×B) = 0.093		

Acidity %: There was a negative proportion between acidity percentages and periods of storage in all treatments in both seasons, as shown in Table 9. Control fruits showed the lowest values. Anyhow, the differences were insignificant during storage at 20°C in the second season. The titratable acidity is an important factor in maintaining the quality of fruits, which is directly related to the organic acids content present in the fruit. Fan *et al*. [11] reported that the decrease in titratable acidity content could be due to the consumption of organic acids by fruits during respiration.

Total Phenols: Total Phenols decreased continuously during the storage period (Table 10). Phenols were significantly lower in untreated control fruits, while 1-MCP treatments attained higher significant values during 2014 and 2015 seasons. Alves *et al*. [31] reported that the decrease in total phenolic levels might be due to breakdown of cell structure in senescence statge during the storage period. The effect of 1-MCP and SA treatments on the maintenance of total phenolic content plausibly may be attributed to delay in senescence [15].

Table 10: Effect of 1-MCP and SA treatments on fruit total phenols (mg gallic acid /100g FW) in 2014, 2015 seasons

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	51.71	51.45	49.71	46.38	40.71	47.99	35.71	30.71	33.21
2µL L^{-1} 1-MCP	51.71	51.38	50.71	46.38	39.38	47.91	34.05	29.71	31.88
1mmol L^{-1} SA	51.71	51.71	50.38	47.38	37.71	47.78	33.38	28.05	30.71
2mmol L^{-1} SA	51.71	51.14	49.81	45.22	38.22	47.22	33.22	28.55	30.88
Control	51.71	50.71	48.38	45.38	35.05	46.25	31.05	25.71	28.38
Mean	51.71	51.27	49.79	46.14	38.21		33.48	28.54	
L.S.D $^{0.05}$	(A) = 1.36, (B) = 1.36, (A×B) = 3.04						(A) = 1.98, (B) = 1.25, (A×B) = 2.80		
				Second season					
1µL L^{-1} 1-MCP	54.05	52.71	51.38	50.31	42.65	50.22	32.71	29.71	31.21
2µL L^{-1} 1-MCP	54.05	52.44	51.28	49.85	40.18	49.56	30.21	28.21	29.21
1mmol L^{-1} SA	54.05	51.71	51.18	48.18	38.05	48.63	28.11	24.78	26.45
2mmol L^{-1} SA	54.05	52.45	51.15	47.48	38.15	48.65	28.25	25.25	26.75
Control	54.05	51.38	50.05	44.38	32.71	46.51	24.05	21.38	22.71
Mean	54.04	52.13	51.01	48.04	38.34		28.66	25.86	
L.S.D $^{0.05}$	(A) = 0.73, (B) = 0.73, (A×B) = 1.63						(A) = 1.23, (B) = 0.78, (A×B) = 1.74		

Table 11: Effect of 1-MCP and SA treatments on fruit ascorbic acid (mg/100g FW) in 2014, 2015 seasons.

	Days of storage at 12°C (B)						Days of shelf life at 20°C (B)		
Treatment (A)	0	7	14	21	28	Mean	4	8	Mean
				First season					
1µL L^{-1} 1-MCP	39.39	28.62	17.89	15.84	14.31	23.21	13.29	12.26	12.78
2µL L^{-1} 1-MCP	39.39	18.40	14.31	13.80	12.77	19.73	12.26	9.20	10.73
1mmol L^{-1} SA	39.39	26.06	17.89	15.84	13.80	22.59	10.22	8.33	9.28
2mmol L^{-1} SA	39.39	26.57	16.35	13.81	13.80	21.98	11.24	8.69	9.96
Control	39.39	27.08	15.84	13.29	12.78	21.67	7.68	7.57	7.62
Mean	39.39	25.34	16.45	14.51	13.49		10.97	9.23	
L.S.D $^{0.05}$	(A) = 2.74, (B) = 2.74, (A×B) = 6.13						(A) = 3.16, (B) = 2.00, (A×B) = 4.48		
				Second season					
1µL L^{-1} 1-MCP	38.12	31.62	20.22	16.51	13.97	24.09	13.62	11.93	12.78
2µL L^{-1} 1-MCP	38.12	20.40	19.44	16.31	13.46	21.55	12.93	10.20	11.56
1mmol L^{-1} SA	38.12	25.06	18.22	15.84	13.46	22.14	10.55	8.67	9.61
2mmol L^{-1} SA	38.12	25.24	18.02	14.13	13.80	21.86	10.58	9.35	9.96
Control	38.12	27.08	18.51	15.29	13.41	22.48	8.24	7.67	7.95
Mean	38.12	25.88	18.88	15.61	13.62		11.18	9.56	
L.S.D $^{0.05}$	(A) = 1.43, (B) = 1.43, (A×B) = 3.20						(A) = 1.74, (B) = 1.10, (A×B) = 2.46		

Ascorbic Acid: Table 11 reveals that ascorbic acid decreased gradually during storage. Fruits treated with 1-MCP maintained significantly higher ascorbic acid content in both seasons compared with control. Ascorbic acid is an important nutrient quality factors, which is very sensitive to degradation due to its oxidation compared with other nutrients during storage. According to Fan *et al*. [11] the decrease in ascorbic acid during storage could be due to the conversion of dehydroascorbic to diketogulonic acid by oxidation.

On conclusion the present work declared that 1-MCP and SA treatments maintained the different fruit quality parameters as it slowed down changes that occurred during ripening leading to deterioration compared with untreated fruits. These treatments reduced acute rise of respiration which is reflected on the different biological changes in fruit. It has a significant positive influence on the changes in the content of TSS, acidity, phenols, ascorbic acid, decay percentages, softening and undesirable colour changes. Using 1 µL L^{-1} 1-MCP showed promising effects for maintaining fruit quality.

REFERENCES

1. Lelievre, J.M., A. Latche, B. Jones, M. Bouzayen and J. Pech, 1997. Ethylene and fruit ripening. Physiol. Plant., 1001: 727-739.

2. Sisler, E.C. and M. Serek, 2003. Compounds interacting with the ethylene receptor in plants. Plant Biol., 5: 473-480.
3. Watkins, C.B., 2006. The use of 1-methylcyclopropene (1-MCP) on fruits and vegetables. Biotechnol Adv., 24: 389-409.
4. Sivakumar, D., Y. Jiang and E.M. Yahia, 2011. Maintaining mango fruit quality during the export chain. Food Res Intl., 44: 1254-63.
5. Osuna-Garcia, J.A., I.C. Morales and E. Gonzalez, 2007. Effect of 1-MCP and hot water treatment on physiology and quality of 'Keitt' mangos. Revista Chapingo Serie Hortic., 13(2): 157-63.
6. Hofman, P.J., G.F. Meiburg and D.C. Joyce, 2001. Ripening and quality responses of avocado, custard apple, mango and papaya fruit to 1-methylcyclopropene. Aust J. Exp. Agric., 41: 567-72.
7. Jiang, Y. and D.C. Joyce, 2000. Effects of 1-methylcyclopropene alone and in combination with polyethylene bags on the postharvest life of mango fruit. Ann Appl Biol., 137: 321-7.
8. Ozeker, E., 2005. Salicylic acid and its effects on plants. E.U. Agriculture J., 42(1): 213-223.
9. Charles, A. and J. Roger, 1988. Inhibition of Ethylene Biosynthesis by Salicylic Acid. Plant Physiol., 88: 833-837.
10. Leslie, C.A. and R.J. Romani, 1988. Inhibition of ethylene biosynthesis by salicylic acid. Plant Physiol., 88: 833-837.
11. Fan, X., J.P. Matches and J.K. Fellowman, 1996. Inhibition of apple fruit 1-aminocyclopropane-1-carboxylic acid oxides activity and respiration by acetyl salicylic acid. J Plant Physiol., 149: 469-471.
12. Vijay, R. and R. sharma, 2016. Effect of pre-harvest application of salicylic acid on the postharvest fruit quality of the Amrapali mango. Indian Journal of Agricultural Sciences, 86: 727-758.
13. Luo, Z., C. Chen and J. Xie, 2011. Effect of salicylic acid treatment on alleviating postharvest chilling injury of 'Qingnai' plum fruit. Postharvest Biol Technol., 62: 115-120.
14. BAL, E. and S. Celik. 2010. The effect of postharvest treatments of salicylic acid and potassium permanganate on the storage of kiwifruit. Bulgarian. Journal of Agricultural Science, 16(5): 576-584.
15. Yan, T., J.G. Shen and C.D. Liu, 1998. Effects of salicylic acid on ripening fruits. Chin. Bull. Bot., 15(3): 61-64.
16. Han, T., Y. Wang, L. Li and X. Ge, 2003. Effect of exogenous salicylic acid on postharvest physiology of peaches. Acta Hort., 628: 583-589.
17. Li, L.P. and T. Han, 2000. Effect of salicylic acid (SA) on quality of stored persimmon. J Beijing Agr. Coll., 15: 49-54.
18. Srivastava, M.K. and U.N. Dwivedi, 2000. Delayed ripening of banana fruit by salicylic acid. Plant Science, 158: 87-96.
19. Holmes, R., T. Campbell and S. Ledger, 1990. Mango picking guide. HortScience, 115: 430-434.
20. Mitcham, B., M. Cantwell and A. Kader, 2003. Method for determining quality of fresh commodities. Pershiables Handling Newsletter Issue No.85.
21. McCollum, T.G., S. D' Aquino and R.E. McDonald, 1993. Heat treatment inhibits mango chilling injury. HortScience, 28(3): 197-198.
22. A.O.A.C. 1980. Official methods of analysis 13th ed. Association of official analytical chemists, Washington, D.C.; USA.
23. Swain, T. and W.E. Hillis, 1959. The qualitative analysis of phenolic constituent. Journal Society Food Agriculture, 10: 63.
24. Mazumdar, B.C. and K. Majumder, 2003. Methods on Physico-chemical Analysis of Fruits, Daya Publ. House, Delhi, India, pp: 93-139.
25. Snedecor, G.W. and W.G. Cochran, 1989. Statistical methods, 8th Ed. lowa State Univ. press, Ames, lowa, USA.
26. Zhi-qiang, L.I., 2009. Effect of 1-methylcyclopropene on ripening and superficial scald of japanese pear (cv. Akemizu) fruit at two temperatures. Fd. Sci. and Technol. Res., 15: 483-490.
27. Zheng Y. and Q. Zhang, 2004. Effect of polyamines and salicylic acid postharvest storage of Ponkan mandarin. Act Hortic., 632: 317-320.
28. Woods, J.L., 1990. Moisture loss from fruits and vegetables. Postharvest News Inform., 1: 195-199.
29. Kazemi, M., M. Aran and S. Zamani, 2011. Effect of salicylic acid treatments on quality characteristics of apple fruits during storage. Am. J. Plant Physiol., 6: 113-119.
30. Jeong, J., D.J. Huber and S.A. Sargent, 2002. Influence of 1-methylcyclopropene (1-MCP) on ripening and cell-wall matrix polysaccharides of avocado fruit. Postharvest Biol Technol., 25: 241-56.
31. Alves, R.E., H. Filgueiras and A. da Silva, 2004. Postharvest ripening of 'Tommy Atkins' mangoes on two maturation stages treated with 1-MCP. Acta Hortic., 645:627-32.