



Intermittent Warming and Methyl Jasmonate Applications to Alleviate Sensitivity of Chilling Injury of Stored Palmer and Sensation Mangos Cultivars



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MANGOS are a sensitive fruit to chilling injury (CI) when stored below 10 °C, manifested by pitting of the surface, browning of the skin, higher susceptibility to decay, failure or irregularity in ripening, and diminishing in the quality of fruits. The efficacy of intermittent warming (IW) combined with four methyl Jasmonate (MeJA) concentrations to alleviate sensitivity chilling injury of Palmer and Sensation cvs. during two successive seasons 2018 and 2019 were studied. The results indicated that all applied concentrations of methyl Jasmonate except for the high concentration with intermittent warming improved quality characteristics, the most pronounced effect was recorded by 1.0 mM MeJA + IW treatments in both storage Phases at 5±1 °C for 15 days followed by 7 days at 20± 2 °C with the two mango cultivars under study, which minimized discarded fruits and chilling injury symptoms as well suppressed weight loss, and loss of pulp firmness. Also, treated fruits of 1.0 mM MeJA plus IW reduced the leakage of ions & total acidity, maintained ascorbic acid and increased TSS%, total pigmentation (carotenoids pulp & anthocyanins peel). Significant differences in enzymes activity, ethylene production and respiration rate in both pulp tissues were detected between this treatment and control fruits. Other favorable effect to the treatment 1.0 with MeJA +IW where it increased (1.0 with MeJA +IW) increased peroxidase and catalase enzymes activities which usually occurs during cold storage, reduced respiration rate and stimulated ethylene production. Sensation mango cv. has a long storability and handling periods than Palmer mango cultivar.

Keyword: Intermittent warming, methyl jasmonate, chilling injury, cold storage, Palmer and Sensation mango cultivars.

Introduction

Mango (*Mangifera indica* L.) is a major fruit crop in both tropical and subtropical regions and is produced in more than 100 countries (Ravindra and Goswami, 2007). Mangoes are of high commercial importance all over the world. Mangoes are famous for being the fruit par excellence. It occupied a leading position among commercial fruits, in addition to being a valuable source of income for producing countries as

it enjoys a long production season and a wide domain, of Fluoridan varieties that have colors attractive (Zheng et al., 2012)

Mango 'Sensation' is a late season cultivar, developed in South Florida, these tropical trees are medium to tall. Produce a fruits medium to small size, dark red and oval shaped with a fragrant yellow flesh and Fibers free (Cecille et al., 2005). However, Palmer cultivar is classed as late season cultivars; it gained some commercial

acceptance in Florida, fruits are medium in size; the color tends to be yellow with blush at maturity, and turns purple long before ripening. The flesh is orange-yellow and has a mild, aromatic flavor, with little fiber, and contains a mono-fetus seed. (Vayssieres et al., 2008).

Mangoes, like many tropical and subtropical fruits, are sensitive to chilling injury (CI) when stored at temperatures below critical temperatures. (Zhao et al., 2006) where the fundamental, symptoms of chilling sensitivity in fruits are briefly described, a schema, suggested two potential causes of chilling injury. The first reason physical changes in membrane lipids, especially phosphatidylglycerol, which lead to changes in membrane characteristic and cellular systems. (Wang, 1994) Additionally, the second involves is due to the deterioration, of the activation functions of some main enzymes in the metabolism process, an example being phosphoenol carboxylase. Several effects of low temperatures non-freezing level are recorded on the kinetic properties of this enzyme (Khaliq et al., 2016).

The main chilling injury symptoms of mangos are redness of the skin or blackening, pitting of the peel, irregular ripeness, reduced odor and flavor, as well as the incidence of decay (Zheng et al., 2012), and symptoms become more severe after removing the fruits from chilling temperature (Ketsa et al., 2000). Mostly, chilling injury prevents the biosynthesis and production of ethylene, and this leads to failure of the maturation process (Nair et al., 2004). This indicates that ethylene biosynthesis correspond, with the onset CI symptoms (Ding et al., 2002). Chilling injury may cause cell wall damage and loss structural wall structural straightening (Zhang et al., 2017), abnormalities of cell wall metabolites involving to pectin degradation, and changes in degrading activities enzymes (Yang et al., 2012), and the age of fruits after harvest is limited. (Wang et al., 2009) Progress has been made in controlling these disturbances through the use of modified atmosphere packaging, chemical treatments, temperature management, and the use of methyl jasmonate prior to storage (Valenzuela et al., 2017).

Generally, intermittent warming (IW) can be elucidation as transferring the fruits periodically from a chilled temperature to a warm temperature for one or more times to increase the resistance of the fruits to low temperatures and avert chilling damage. Thus, the fruits are stored at temperatures

below the critical temperature. (Artes, et al., 1998). Intermittent warming is primarily used to alleviate the severity of chilling tissues; it also maintains fruit quality during storage (Liu et al., 2015). The common hypothesis of the intermittent warming mechanism is that an increase, in temperature during chilling exposure ordinarily leads to higher activities metabolic and permits tissues to metabolizesurplus intermediates or toxic substances cumulative during cooling. Short-term warmingprocess of the cooling tissue may help to repair damage to membranes or organelles or metabolicpathways, as it works to regenerate any substances depleted or not manufactured during cooling (Kramer & Wang 1989and Seibert et al., 2010).

Another hypothesis relative to the intermittent warming mechanism illustrate that converting the temperature from cool to warm and then from warm to cool may lead to readjustment a metabolic as it increases the synthesis of unsaturated fatty acids. It also leads to elongate fatty acids and de-saturate them when the temperature changes from warm to cool. It is possible that this change affects the fluidity of the membrane and increase low temperature tolerance. (Wang, 1994, Ladaniya, 2011 and Alex et al., 2019). Intermittent warming was correlated with safeguarding high levels of phospholipids in the membranes, increasing the degree of unsaturation in membranes acids, and preventing an excess of sterols, increased concentrations of squalene, polyamine and long-chain aldehyde. All of these factors contribute to the mitigation of chilling injury (Biswas et al., 2015)

Jasmonic acid (3-oxo-2-20-cis-pentenyl-cyclopentane-1-acetic acid, JA) is classified as a substance that is synthesized in higher plants and leads to growth-regulating. Jasmonic acid, methyl ester (MeJA) and isoleucine conjugate (JA-Ile) are recognized as derivatives of category of fatty acids called jasmones (JAs). Firstly, JAs are, specified as a hormone related with stress and are also contributed in regulating significant growth and development processes (Wasternack and Hause, 2013). MeJA has a considerable role in biotic and abiotic safeguarding defense mechanisms (Cheong and Choi, 2003). Generally, JAs are applied to adjust responses by: altering plant growth and development during far-reaching signals (Motallebi et al., 2015), and organizing of secondary metabolism plant. Via, stimulating production of compounds toxic (Moreira et al.,

2012) or raising the activity and density of the reactive oxygen species to safeguard against abiotic stresses and promote, the rate of recovery from damage (Cao et al., 2009).

It has been previously reported by Jin et al. (2006) that jasmonic acid (JA), methyl jasmonate (MeJA) and methyl ester are naturally present in a variety of higher plants. It is also a final product of the enzymatic oxidation of the poly-unsaturated fatty acid, and lipoxigenase which is central enzyme to this pathway.

Application of Jasmonate increases stress tolerance to many plant species. Also, exposure to methyl jasmonate (MeJA) vapor leads to a reduced in papaya fruit decay after post-harvest (Yanli et al., 2019). Besides, the storage duration of fresh sweet pepper and celery slices was extended by reducing physiological degradation and limiting microbial growth after methyl jasmonate treatment (Ding et al., 2002). The reason for reducing chilling damage by (MeJA) may be a promote in the antioxidant enzymes activity's and an increase in unsaturated fatty acids ratio (Cao et al., 2009). The relationship between (MeJA) and ethylene has been demonstrated, a tentative slow-down in fruits ripening was recorded by ethylene biosynthesis (Fan et al., 2016). Moreover, ethylene production in pears and apples is reduced or inhibited in the fruit ripening stage when (MeJA) is used externally (Wang et al., 2019)

The main goal of this study was to evaluate intermittent warming mechanism and methyl jasmonate as supplementary refrigeration treatments to alleviation sensitivity chilling injury of Palmer and Sensation mango cultivars.

Materials and Methods

This study was carried out during the two successive seasons of 2018 and 2019 on two Mango cvs.: Palmer and Sensation (*Mangifera indica* L.) to evaluate some postharvest treatments to alleviate, mango fruits sensitivity to chilling injuries. Mango fruits were harvested from a commercial orchard in South Tahrir sector, Behira Governorate. Mature mango fruits were picked according to maturity indices which defined fully mature fruits that having outgrown shoulders, formation of depression at the stem end, but remaining firm and green (Medlicott et al 1990). Palmer and Sensation were harvested on the second week of Sept for both seasons.

The harvested were early morning and directly transferred the fruits to the Horticultural Department, Faculty of Agriculture, Ain Shams University. Fruits of each cultivar were uniform size and free of defects, and then washed in chlorinated water chlorex (0.05% Sodium hypochlorite) at 100 ppm for 2 min., air dried and sorted. Fruits were weighed for recorded their initial fresh weight then subjected to pre-storage treatments:

Methyl jasmonate (MeJA)

Mango fruits were dipping for 5 minutes with four concentrations of methyl jasmonate (0, 0.5, 1.0 and 2.0 mM).

Intermittent warming (IW)

Fruits stored at 5±1°C for 3 days, then transferred to a high temperature at 20±2°C for 8 hr. and repeated until the end of cold storage (4 cycles of 72 hr. cold storage followed by 8 hr. warm). The treatments used were :

- Control rinsed in distilled water
- Intermittent warming (IW) only.
- MeJA at 0.5 mM.
- MeJA at 0.5 mM+ IW.
- MeJA at 1.0 mM.
- MeJA at 1.0 mM+ IW.
- MeJA at 2.0 mM.
- MeJA at 2.0 mM+ IW.

After finished from all treatments the fruits of each treatment were divided into 4 replicates, each replicate were packed in carton boxes to hold 6 fruits. The number of the fruits used was 192 (8 treatments X 4 replicates X 6 fruits) for each mango cultivar. The treatments were arranged in a randomized complete blocks design. Fruits of all treatments were transferred to the cold store (5±1°C and 88±5% RH) for 15 days before transferred to the ripening room conditions (20±2°C) for 7 days.

The initial sample was taken randomly at the beginning of the cold storage period (0 days) After that, samples were taken at the end of the storage periods, for 15 days of cold storage and 7 days of ripening rooms from each replicate of all treatments. Regarding the physiological measurements, it including respiration rate, ethylene production, catalase and Peroxidase enzymes active, were taken one time after finished of storage periods (the end of experiment and way out fruits from ripening room.

The following parameters were evaluated

Fruit physical analysis

Discarded fruits %: The number of decayed fruits was recorded periodically, expressed as a percentage of the total number of fruits.

Visual chilling injury symptoms (Scale): Symptoms of chilling injury were individually evaluated in each fruit with a 5-points hedonic scale based on the percentage of the external surface of the affected fruit (pitting or brown color): 0 = none (free); 1 = 1-10% damaged space (very slight); 2 = 11-20% damaged space (minor); 3 = 21-30% damaged space (moderate) and 4 => 30% damaged space (sever) .The chilling injury scale was calculated using the following formula:

$CI = \Sigma (\text{hedonic scale value}) \times (\text{number of fruits with corresponding scale number}) / \text{total fruits number in the sample}$ (Sayyari et al., 2009)

Weight loss %: The initial weight of mangos was recorded, and then the weight loss of fruits was calculated by weight immediately after treatments application and at the end the storage periods (the end of cold storage at 5 + 1 ° C for 15 days and storage of ripening room at 20+2°C for 7 days).

Fruit firmness (Kg/f): Fruit firmness was recorded by means of a Wagner® Fruit Firmness Tester, model FT-327, equipped with an 8mm plunger tip a digital basic force gauge .The firmness values were calculated by kilo gram force (Kg/f).

Chemical constituents

Total Soluble solids %: was determined according to A.O.A.C. (2005).

Total acidity (as g Citric acid/100 g fruit fresh weight) was determined according to A.O.A.C. (2005).

L-ascorbic acid content (mg/100g fruit fresh weight) was determined following the methods by A.O.A.C. (2005)

Solute leakage (% EC leakage): Weighed 10 g of mango tissue disks, added 30ml of deionized water, and stirred magnetically for 15 minutes. The electrical conductivity (EC) of a catalytic solution was measured with an electrometer. The experience was repeated again but after homogenization of the tissues in the mixer and measurement of the EC level. The percentage

of solute leakage was calculated as the EC leak using the method described by Mirdehghan et al. (2007)

Total carotenoid pulp content: (mg/100 g fresh weight) was decided, according to the method of Wellburn (1994).

Anthocyanin peel content: (mg/100 g fresh weight) was decided, according to the method of Wrolstad et al. (2005).

Physiological attributes

Respiration rate: (mg CO₂/kg fresh fruits / hr.): The producer of carbon dioxide from the mangoes was evaluated immediately after application of the treatments as an initial sample and after finished of storage periods (the end of experiment and way out fruits from ripening room). The air-flow was passed through concentrated NaOH to ensure that the air-flow was free of carbon dioxide, before passing into 1- liter container - one fruit / jar was considered as one replicate. The out -flow of air was then introduced into 100 mL of 0.1 N NaOH for 1 hour. This solution was then titrated against 0.1 N HCl and levels of carbon dioxide produced by fresh fruits were measured as (mg CO₂ / kg fresh fruit / hour), according to A.O.A.C. (2005)

Ethylene production: (µl C₂H₄/Kg fruit/hr.): The rate of ethylene production was determined by incubating one fruit in 1 liter glass containers. After two hours of incubation, one ml gas sample was drawn from each jar vacuum and injected into a gas chromatography model (Hewlett Packard 5890 Series II, USA). The ethylene production rate was expressed in µl C₂H₄/Kg fruit/hr.

Enzymes activities: Peroxidase enzyme activity (as µmol min⁻¹ mg⁻¹ protein.) was determined according to Herzog and Fahimi (1973) and Catalase enzyme activity (as µmol min⁻¹ mg⁻¹ protein.) was estimated followed by Claiborne (1985).

Statistical analysis

Data were analyzed for statistical significant differences using MSTAT-C software (MSTAT, Michigan University East Lansing). Duncan multiple rang test (LSR) at 5% level was completed to define any significant difference among various treatments, according to Snedecor and Cochran (1990).

Results and Discussion

Fruit physical analysis

Discarded fruits %

It is clear from data in Table 1 that all applied treatments except 2.0 mM MeJA were effective in minimizing discarded fruits % except 2.0 mM MeJA in Palmer and Sensation mangoes during 2018 and 2019 seasons. After cold storage at $5 \pm 1^\circ\text{C}$ for 15 days, the significant effect on reducing discarded fruits percentage were recorded with 1.0 mM MeJA + IW (intermittent warming) treatment followed by 0.5 mM MeJA + IW which recorded zero discarded fruits in both mango cultivars. However, after 7 days in

the ripening room at $20 \pm 2^\circ\text{C}$ the percentage of discarded fruits greatly increased especially with 2.0 mM MeJA treatment where reaching about (47.17 %). Moreover, Palmer mango cv. exhibited higher values of discarded fruits than Sensation mango cv. under the same conditions which means that Sensation mango cv. has a long storability and handling periods than Palmer mango cv. On the other side, the least discarded fruits % was recorded by the treatment of 1.0 mM MeJA + IW in the two mango cvs. and the two studied seasons. The second treatment in minimizing discarded % was 0.5 mM MeJA + IW in both mango cvs. and both seasons.

TABLE 1. Effect of intermittent warming and methyl jasmonate treatments on discarded fruits % and chilling injury (Scale) of two mango cvs. under cold storage at $5 \pm 1^\circ\text{C}$ or ripening room at $20 \pm 1^\circ\text{C}$ during 2018 and 2019 seasons.

Treatments	Days in ripening room at $20 \pm 2^\circ\text{C}$ after 15 days in cold storage at $5 \pm 1^\circ\text{C}$							
	Discarded fruits (%)				Chilling injury (Scale)			
	Palmer		Sensation		Palmer		Sensation	
	0 days	7 days	0 days	7 days	0 days	7 days	0 days	7 days
Season 2018								
Control	25.00 b	41.67 a	12.50 b	33.34 a	1.46 ab	2.53 b	1.07 b	2.10 ab
I.W	12.50 c	25.00 b	4.16 cd	20.83 b	1.05 bc	1.60 c	0.73 bc	1.46 cd
0.5 mM JA	8.34 cd	16.67 c	4.16 cd	12.50 c	0.88 cd	1.25 cd	0.55 c	1.11 de
0.5 mM JA + I.W	0.00 e	8.34 d	0.00 d	4.16 de	0.00 e	0.88 d	0.00 d	0.64 e
1.0 mM JA	4.18 de	12.50 cd	0.00 d	8.34 cd	0.62 d	1.00 cd	0.00 d	0.71 e
1.0 mM JA + I.W	0.00 e	0.00 e	0.00 d	0.00 e	0.00 e	0.00 e	0.00 d	0.00 f
2.0 mM JA	33.30 a	45.83 a	20.83 a	37.50 a	1.76 a	3.11 a	1.53 a	2.65 a
2.0 mM JA + I.W	12.50 c	29.17 b	8.34 bc	25.00 b	1.29 bc	2.36 b	1.12 b	1.85 bc
Season 2019								
Control	16.67 b	45.83 b	20.83 a	37.50 b	1.35 ab	2.74 a	0.92 ab	2.29 ab
I.W	8.34 c	33.33 c	8.34 b	25.00 c	0.98 bc	1.82 bc	0.75 b	1.63 c
0.5 mM JA	12.50 bc	20.83 d	0.00 c	16.67 d	0.62 c	1.43 cd	0.00 c	1.21 cd
0.5 mM JA + I.W	0.00 d	4.17 ef	0.00 c	0.00 e	0.00 d	0.96 d	0.00 c	0.77 d
1.0 mM JA	0.00 d	8.34 e	0.00 c	4.17 e	0.00 d	0.83 d	0.00 c	0.00 e
1.0 mM JA + I.W	0.00 d	0.00 f	0.00 c	0.00 e	0.00 d	0.00 e	0.00 c	0.00 e
2.0 mM JA	29.17 a	54.17 a	16.67 a	45.83 a	1.75 a	3.28 a	1.16 a	2.40 a
2.0 mM JA + I.W	8.34 c	25.00 d	4.17 bc	20.83 cd	1.07 b	2.15 b	0.66 b	1.79 bc

Values followed by the same letter (s) are not significantly different at 5% level

0 days: Out of mango fruits from storage for 15 days at $5 \pm 1^\circ\text{C}$

I.W: The fruits exposed to intermittent warming every three days at 20°C for 8 hr.

Visual chilling injury symptoms (Scale)

An evident decrease in, chilling injury scale in both mango cvs were recorded in Table 1 due to all applied treatments than control in both studied seasons except the treatment of 2.0mM methyl jasmonate which recorded high values of chilling injury scale than control. After removed the fruits from cold storage at $5 \pm 1^\circ\text{C}$ for 15 days the least scale of chilling injury were recorded by the treatments of 0.5 mM MeJA +IW , 1.0 mM MeJA and 1.0 mM MeJA + IW in both Palmer and Sensation mango cvs and both studied seasons. No clear differences between the two mango cvs in their sensitivity to chilling injury but generally it could be noticed that Sensation mango cv. exhibited less scale of chilling injury than Palermangoes. However, during fruit ripening at $20 \pm 2^\circ\text{C}$ chilling injury scale were increased but the applied treatments were effective in reducing chilling injury scale than control except the treatment of 2.0 mM MeJA which exhibited higher values of chilling injury scale than control in both mango cvs and both studied seasons . Sensation ripening mango fruits were recorded less values of chilling injury scale than Palermangoes cv. Same data of discarded fruits % and chilling injury scale showed that

Sensation mango has high storage and marketing ability than Palmer fruits.

Weight loss %

Data in Table 2 show that weight loss % greatly affected with all applied treatments than control either after 15 days in cold storage at $5 \pm 1^\circ\text{C}$ or after 7 days in ripening room at $20 \pm 2^\circ\text{C}$ in both Palmer and Sensation mangos . After cold storage duration, all applied treatments recorded less values of weight loss % than control except the treatment of 2.0 mM MeJA in bothmango cvs. andboth seasons which recorded high values of weight loss than control. The least weight loss % was recorded by the treatment of 1.0 mMMeJA+ IW in both Palmer and Sensation mango cvs. andboth seasons. However Sensation mango cv. recorded less weight loss values than Palmer cv. regardless of applied treatment. Moreover, after 7 days of fruit of ripening room at $20 \pm 2^\circ\text{C}$, weight loss % greatly increased but followed the same trend found in cold storage durations. Also Sensation mango cv. followed the same trend found in cold storage durations where it recoded less weight loss % than Palmer mangos regardless of the used treatments.

TABLE 2. Effect of intermittent warming and methyl jasmonate treatments on weight loss % and fruit firmness (Kg/ f.) of two mango cvs. under cold storage at $5 \pm 1^\circ\text{C}$ or repining room at $20 \pm 1^\circ\text{C}$ during 2018 and 2019 seasons.

Treatments	Days in ripening room at $20 \pm 2^\circ\text{C}$ after 15 days in cold storage at 5 ± 1							
	Weight loss (%)				Fruit firmness (Kg/ f.)			
	Palmer		Sensation		Palmer		Sensation	
	0 days	7 days	0 days*	7 days	0 days	7 days	0 days	7 days
Season 2018								
Control	3.22 b	10.40 b	2.68 ab	8.07 b	9.1 d	3.0 e	9.8 e	4.4 d
I.W	2.81 bc	8.66 c	2.35 b	6.14 cd	10.4 c	4.1 cd	11.6 cd	5.0 cd
0.5 mM JA	2.65 cd	7.20 d	2.17 b	5.91 d	11.0 b	4.4 c	12.1 c	5.3 c
0.5 mM JA + I.W	2.17 de	6.37 e	1.48 c	4.65 e	13.1 a	6.0 ab	14.7 a	6.8 ab
1.0 mM JA	2.31 de	6.11 ef	1.64 c	5.21 e	12.6 a	5.3 b	13.4 b	6.2 b
1.0 mM JA + I.W	1.86 e	5.59 f	1.33 c	3.87 f	13.5 a	6.2 a	14.7 a	7.3 a
2.0 mM JA	3.68 a	12.47 a	3.15 a	9.16 a	7.8 e	1.9 f	9.2 e	3.1 e
2.0 mM JA + I.W	3.00 bc	9.22 c	2.31 b	6.83 c	9.6 cd	3.6 de	11.0 d	5.0 cd
Season 2019								
Control	3.65 a	10.85 b	3.14 ab	9.16 b	8.7 cd	3.2 d	9.5 d	4.0 ef
I.W	3.11 b	9.52 c	2.63 bc	7.05 cd	9.7 bc	3.6 d	11.1 c	4.7 cd
0.5 mM JA	2.57 c	8.00 d	2.31 c	6.68 d	10.6 b	4.6 c	12.3 b	5.1 c
0.5 mM JA + I.W	2.03 d	6.12 e	1.63 d	4.11 ef	12.4 a	5.7 b	14.2 a	7.3 ab
1.0 mM JA	2.11 cd	5.56 ef	1.77 d	4.74 e	12.8 a	5.1 bc	13.0 b	6.9 b
1.0 mM JA + I.W	1.71 d	5.40 f	1.45 d	3.52 f	13.1 a	6.5 a	15.1 a	7.6 a
2.0 mM JA	3.88 a	12.12 a	3.31 a	10.27 a	8.1 d	2.3 e	9.1 d	3.5 f
2.0 mM JA + I.W	3.41 ab	10.60 b	2.74 bc	7.54 c	9.0 cd	3.3 d	10.6 c	4.4 de

Values followed by the same letter (s) are not significantly different at 5% level

0 day: Out of mango Fruits from storage for 15 days at $5 \pm 1^\circ\text{C}$

Initial sample: (beginning of cold storage) :-

Fruit firmness Kg/f recorded (16.1 and 15.7. for Palmer cv.) & (16.9 and 17.5 for Sensation cv.) during 2018 and 2019 seasons.

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Fruit firmness (Kg/force)

As it shown in Table 2 a greatly affect to all applied treatments on preservation the losses of fruit firmness were noticed after 15 days in cold storage at $5 \pm 1^\circ\text{C}$ or after 7 days in ripening room at $20 \pm 2^\circ\text{C}$ in the two studied seasons. After cold storage all applied treatments were superior than control in recording high values of fruit firmness except the treatment of 2.0 mM MeJA in both seasons and both mango cvs.. The highest fruit firmness values were recorded by the treatment of 1.0 mM MeJA + IW in both seasons and both mango cvs. . However a general finding showed that Sensation mango cv. exhibited an evident increase in fruit firmness than Palmer cv. regardless of applied treatments or storage types. Additionally, after finished from ripening durations a sharp decrease in fruit firmness was recorded either with control or with the applied treatments. However, similar trend to those found in fruit firmness after finished from cold storage duration was also found after finished from ripening durations.

In this respect, Zhang et al. (2016) mentioned that, chilled fruit was lost more weight than the non-chilled fruit after being transferred to the ripening chamber. Also, Bhoomica et al. (2015) explained that, the abnormal metabolism associated with an increase in the respiratory rate of the damaged tissues may result in microscopic cracks in the peel and pits. Aghdam and Bodbodak (2013) indicated that applications of jasmonate through enhanced membrane integrity, thermal shock protein accumulation and antioxidant system activity. Likewise Fan et al. (2016), determined that the using of MeJA enhanced the solubility of polysaccharides in the cell wall while preserving post-harvest quality and attenuated cold injury, including inhibition of endogenous structural symptoms .

A great effect of intermittent warming was also mentioned by Mohamed et al. (2013) who reported that, the intermittent warming mechanism promote tissue tolerance to chilled and reduce CI Symptoms of the fruit. However, intermittent warming is the alteration of lower temperatures during storage by one or more periods of warm temperatures. The application of IW must be done before the CI becomes irreversible. Conversely, Zhang et al. (2017) explained that, if the critical time at the cooling temperature is overtake, and the CI exceeds the recovery phase, the raise temperature will only accelerate the degradation, so, timing of treatment is important, and early detection of CI is critical.

Also, Wang (1994) demonstrates that, during IW the unsaturated fatty acids are synthesized by the induced elongation of the fatty acids during warming and de-saturating the fatty acids during cooling. Thus remain more liquid than fruit membranes which are kept at a consistently low temperature (Mikami and Murata 2003) Similarly, Liu et al. (2015) suggested that IW may then expedite repair of membranes damaged in cryogenic tissue and accretion subsequent resistance to CI by preserving the integrity of cell membranes.

Fruit constituents

Total soluble solids %

As it shown in Table 3 T.S.S. % of Palmer and Sensation mangos greatly affected with applied treatments either during cold storage or ripening periods in both studied seasons. All applied treatments exhibited higher values of T.S.S. % than control in both seasons and both mangos cvs. with significant differences between then expect the treatment of 2.0 mM MeJA which similar to control. The high values of TSS % during cold storage were recorded by 0.5 mM MeJA+ IW and 1.0 mM MeJA+ IW without significant differences between them in both seasons and both mango cvs. . However, during ripening period, an evident increase in TSS% were obtained with all applied treatments and control in both seasons and both mango cvs.. The highest values of TSS% in both mango cvs, were recorded by 1.0 mM MeJA+ IW comparad with other treatments or control .Additionally, Sensation mango cv. exhibited higher values of TSS% than Palmer mango cv under the same conditions.

Total acidity (g Citric acid/100 g fresh pulp)

Table 3 showed that TA values were varied between the applied treatments and the two mango cvs. in both seasons. After finished from cold storage duration, the least TA values were obtained with 0.5 or 1.0 mM MeJA plus IW in both seasons and both mango cvs. However, during ripening period, an evident reduction in total acidity with all applied treatments and control and both mango cvs. The least TA values were recorded by 0.5 or 1.0 mM MeJA + IW in both seasons. Sensation mango cv, exhibited less TA values than Palmer mango regardless of the applied treatments and during cold storage or ripening periods. It is well known that the reduction in total acidity with advanced in fruit repining attributed to consumption of these acids in fruit respiration through Krebs cycle pathway.

TABLE 3. Effect of intermittent warming and methyl jasmonate treatments on total soluble solids % and total acidity % of two mango cvs. under cold storage at 5 ± 1 °C or ripening room at 20 ± 1 °C during 2018 and 2019 seasons.

Treatments	Days in ripening room at 20 ± 2 °C after 15 days in cold storage at 5 ± 1							
	T.T.S. %				TA %			
	Palmer		Sensation		Palmer		Sensation	
	0 days*	7 days	0 days*	7 days	0 days	7 days	0 days	7 days
Season 2018								
Control	10.1 c	12.7 de	11.4 e	13.6 ef	0.77 ab	0.47 b	0.68 ab	0.42 ab
I.W	10.7 b	13.8 c	12.3 cd	14.7 d	0.74 a-c	0.40 c	0.65 bc	0.34 c
0.5 mM JA	11.0 ab	14.7 b	12.6 bc	16.3 c	0.71 b-d	0.36 cd	0.62 cd	0.31 cd
0.5 mM JA + I.W	11.4 a	15.3 b	12.9 ab	17.5 ab	0.65 d	0.30 e	0.61 cd	0.25 de
1.0 mM JA	11.1 ab	15.1 b	12.4 bc	16.9 bc	0.69 cd	0.33 e	0.56 d	0.27 de
1.0 mM JA + I.W	11.3 a	16.2 a	13.2 a	18.1 a	0.67 d	0.34 de	0.57 d	0.24 e
2.0 mM JA	10.0 c	12.1 e	11.0 e	13.0 f	0.79 a	0.53 a	0.71 a	0.46 a
2.0 mM JA + I.W	10.6 b	13.0 cd	11.9 d	14.1 de	0.71 b-d	0.41 c	0.63 bc	0.37 bc
Season 2019								
Control	9.6 d	12.3 ef	10.6 e	12.8 d	0.83 ab	0.51 b	0.74 ab	0.46ab
I.W	10.3 c	13.4 d	11.7 d	13.9 c	0.80 bc	0.46 b	0.67 cd	0.37 c
0.5 mM JA	10.9 b	14.5 c	12.3 c	15.9 b	0.76 cd	0.41 cd	0.66 cd	0.36 c
0.5 mM JA + I.W	11.8 a	16.0 ab	13.2 b	17.1 a	0.71 d	0.35 e	0.65 d	0.29 d
1.0 mM JA	11.7 a	15.5 b	12.8 bc	17.4 a	0.75 cd	0.36 de	0.59 e	0.29 d
1.0 mM JA + I.W	12.0 a	16.6 a	13.9 a	17.7 a	0.72 d	0.38 de	0.62 de	0.26 d
2.0 mM JA	9.7 d	11.7 f	10.5 e	12.2 d	0.87 a	0.57 a	0.78 a	0.50 a
2.0 mM JA + I.W	10.3 c	12.6 e	11.7 d	13.8 c	0.79 bc	0.49 b	0.71 bc	0.41 bc

Values followed by the same letter (s) are not significantly different at 5% level

0 day: Out of mango Fruits from storage for 15 days at 5 ± 1 °C

Initial sample: (beginning of cold storage):-

T.T.S. % recorded (8.9 and 8.4 for Palmer cv.) & (10.2 and 9.5 for Sensation cv.) during 2018 and 2019 seasons.

TA % recorded (0.83 and 0.89 for Palmer cv.) & (0.76 and 0.81 for Sensation cv.) during 2018 and 2019 seasons.

L-ascorbic acid content (mg/100g fruit fresh weight)

Data in Table 4 illustrate the effect of intermittent warming (IW), methyl jasmonate (MeJA) and their combinations on L-ascorbic acid contents of two mango cvs stored at 5 ± 1 °C for 15 days followed by 7 days at 20 ± 2 °C in two studied seasons. An evident increase in L-ascorbic acid values were recorded with all treatments than control in both mango cvs. The highest L-ascorbic values after cold storage period were obtained with 0.5 mM MeJA + IW, 1.0 mM MeJA and 1.0 mM MeJA + IW in both mangos and both studied seasons. On contrary, the treatment of 2.0 mM MeJA recorded less or similar L-ascorbic acid values than control. However, Sensation mango cv. was superior than Palmer mango cv. in L-ascorbic acid content regardless of the applied treatments. After ripening period at $20 \pm$

2 °C for 7 days, a reduction of L-ascorbic acid values was generally recorded but the treatments of 0.5 mM MeJA + IW and 1.0 mM MeJA + IW were superior than other treatments in recording the highest L-ascorbic acid values. Additionally, Sensation mango cv. contained more L-ascorbic acid values than Palmer mango cv. regardless of the used treatments.

Solute leakage % (EC)

Data in Table 4 show that the solute leakage greatly affected with all applied treatments in both mango cvs, and both studied seasons. It is well known that as solute leakage decreased, fruit quality and storage ability increased, so any treatment decreased solute leakage value considered a favorite treatment. All applied treatments decreased solute leakage % than control except the treatment of 2.0 mM MeJA in both mango cvs, after cold storage durations

However, after ripening period an evident increase in solute leakage % was obtained, but the treatment of 1.0 mM MeJA + IW was effective than other treatments in recording less solute leakage % in both mango cvs. in both studied seasons. Sensation mango cv., in general, exhibited less values of solute leakage which means that Sensation mango cv. had long storage ability than Palmer mango cv.

Total carotenoids pulp content (mg/100 g fresh weight)

It is clear from data in Table 5 that total carotenoids of fruit pulp in Palmer and Sensation

mango cvs. greatly affected with applied treatments during the two studied factors. However, after finished from cold storage duration, all applied treatments exhibited high values of total pulp carotenoids than control except the treatment of 2.0 mM MeJA . An evident increase in total pulp carotenoids after ripening period in both mango cvs. with all used treatments but the treatment of 1.0 mM MeJA + IW was superior than other treatments. In addition, Palmer mangos was superior than Sensation in recording highest values of total carotenoids regardless of the used treatments.

TABLE 4. Effect of intermittent warming and methyl jasmonate treatments on L-ascorbic acid (mg/100g fruit f.w.) and solute leakage % (EC) of two mango cvs. under cold storage at 5 ± 1 ° C or ripening room at 20 ± 1 ° C during 2018 and 2019 seasons.

Treatments	Days in ripening room at 20±2° C after 15 days in cold storage at 5±1							
	L-ascorbic acid				Solute leakage %(EC)			
	Palmer		Sensation		Palmer		Sensation	
	0 days	7 days	0 days	7 days	0 days	7 days	0 days	7 days
Season 2018								
Control	38.7 de	25.6 e	47.1 cd	33.6 ef	25.1 b	36.1 b	23.9 b	32.8 ab
I.W	41.5 cd	31.9 c	48.3 c	37.5 cd	23.8 b	32.4 cd	20.4 cd	29.7 c
0.5 mM JA	43.6 b	33.4 c	50.4 b	40.1 c	21.5 c	30.5 d	18.7 d	26.6 d
0.5 mM JA + I.W	44.1 ab	37.7 ab	51.7 ab	45.6 ab	19.4 d	26.1 e	16.1 e	21.2 ef
1.0 mM JA	45.7 a	36.1 b	51.5 ab	43.3 b	18.0 de	27.2 e	15.8 e	23.4 e
1.0 mM JA + I.W	46.1 a	39.3 a	53.2 a	47.3 a	17.1 e	25.6 e	14.6 e	19.7 f
2.0 mM JA	37.2 e	23.8 e	44.0 e	31.4 f	27.5 a	41.4 a	26.1 a	35.4 a
2.0 mM JA + I.W	40.1 cd	28.0 d	46.2 d	35.3 de	24.3 b	34.8 bc	22.2 bc	31.5 bc
Season 2019								
Control	41.4 d	23.8 e	44.9 c	31.2 d	28.5 ab	41.2 a	26.3 a	37.1 ab
I.W	42.7 c	28.3 d	47.4 b	38.7 c	24.3 c	38.3 b	21.8 b	33.5 c
0.5 mM JA	45.9 b	31.7 c	47.7 b	38.1 c	20.0 d	33.1 c	19.2 c	28.1 d
0.5 mM JA + I.W	46.3 ab	39.1 ab	49.2 ab	43.3 ab	17.9 e	27.9 d	15.8 de	24.6 e
1.0 mM JA	46.6 ab	37.2 b	48.1 b	42.0 b	18.8 de	25.3 d	17.2 d	25.7 de
1.0 mM JA + I.W	47.4 a	40.8 a	50.5 a	46.4 a	16.7 e	22.1 e	15.1 e	21.3 f
2.0 mM JA	37.9 e	21.6 f	41.4 d	27.2 e	30.2 a	43.4 a	27.4 a	39.4 a
2.0 mM JA + I.W	42.1 cd	25.8 e	43.8 c	32.9 d	26.6 b	37.1 b	20.6 bc	34.6 bc

Values followed by the same letter (s) are not significantly different at 5% level

0 day: Out of mango Fruits from storage for 15 days at 5±1°C

Initial sample: (beginning of cold storage):-

L-ascorbic acid recorded (50.3 and 51.5, for Palmer cv.) & (56.6 and 53.8 for Sensation cv.) during 2018 and 2019 seasons.

Solute leakage % recorded (13.6 and 12.1, for Palmer cv.) & (11.7 and 10.3 for Sensation cv.) during 2018 and 2019 seasons

TABLE 5. Effect of intermittent warming and methyl jasmonate treatments on total carotenoids pulp and anthocyanin peel (mg / 100g f.wt.) of two mango cvs. under cold storage at 5 ± 1 °C or repining room at 20 ± 1 °C during 2018 and 2019 seasons.

Treatments	Days in ripening room at 20±2° C after 15 days in cold storage at 5±1							
	Carotenoid pulp				Anthocyanin peel			
	Palmer		Sensation		Palmer		Sensation	
	0 days*	7 days	0 days*	7 days	0 days	7 days	0 days	7 days
Season 2018								
Control	0.434 c	0.822 de	0.371 cd	0.711 e	0.249 c	0.445 de	0.322 cd	0.571 d
I.W	0.485 bc	0.874 cd	0.422 bc	0.813 cd	0.283 bc	0.559 cd	0.367 bc	0.685 cd
0.5 mM JA	0.513 ab	0.951 bc	0.451 b	0.867 bc	0.324 ab	0.663 bc	0.391 b	0.773 bc
0.5 mM JA + I.W	0.574 a	1.21 a	0.483 ab	0.952 a	0.361 a	0.837 a	0.453 a	0.918 a
1.0 mM JA	0.508 ab	1.06 b	0.462 ab	0.923 ab	0.334 ab	0.764 ab	0.429 ab	0.866 ab
1.0 mM JA + I.W	0.563 a	1.28 a	0.513 a	0.917 ab	0.348 ab	0.809 a	0.415 ab	0.951 a
2.0 mM JA	0.411 c	0.726 e	0.357 d	0.678 e	0.241 c	0.354 e	0.284 d	0.391 e
2.0 mM JA + I.W	0.460 bc	0.842 cd	0.389 cd	0.760 de	0.316 b	0.522 d	0.308 cd	0.652 cd
Season 2019								
Control	0.396 cd	0.744 d	0.336 cd	0.608 de	0.221 c	0.398 de	0.283 d	0.491 cd
I.W	0.411 cd	0.798 cd	0.384 bc	0.716 c	0.246 bc	0.514 cd	0.307 cd	0.567 bc
0.5 mM JA	0.452 bc	0.879 bc	0.417 ab	0.759 bc	0.264 bc	0.583 bc	0.368 bc	0.644 b
0.5 mM JA + I.W	0.511 a	0.982ab	0.431 ab	0.828 ab	0.295 ab	0.749 a	0.411 ab	0.826 a
1.0 mM JA	0.481 ab	0.904 bc	0.465 a	0.869 a	0.304 ab	0.685 ab	0.395 ab	0.765 a
1.0 mM JA + I.W	0.517 a	1.02 a	0.455 a	0.912 a	0.338 a	0.776 a	0.428 a	0.872 a
2.0 mM JA	0.364 d	0.624 e	0.313 d	0.557 e	0.213 c	0.355 e	0.251 d	0.414 d
2.0 mM JA + I.W	0.423 bc	0.775 d	0.367 c	0.663 cd	0.258 bc	0.485 cd	0.319 cd	0.619 b

Values followed by the same letter (s) are not significantly different at 5% level

* Out of mango fruits from storage for 15 days at 5±1°C

Initial sample :-

Carotenoids pulp mg / 100g f.w. recorded (0.197 and 0.169, for Palmer cv.) & (0.176 and 0.153 for Sensation cv.) during 2018 and 2019 seasons.

Anthocyanin peel mg / 100g f.w. recorded (0.118 and 0.104, for Palmer cv.) & (0.137 and 0.141 for Sensation cv.) during 2018 and 2019 seasons.

Anthocyanin pigment peel content (mg/100 g fresh weight)

An evident increase in anthocyanins peel pigment (Table 5) was obtained in both mango cvs. due to the applied treatments. The highest values of anthocyanin peel content were obtained with 0.5 or 1.0 mM MeJA plus IW in both studied seasons and both mango cvs. After repining period highest values of anthocyanin peel content were obtained with all used treatments in both seasons, and the highest values were also recorded by 0.5 or 1.0 mM MeJA plus IW treatments. Moreover, Sensation mango cv, recorded highest values of anthocyanin skin regardless of the used treatments.

Yang et al. (2012) reported that, accumulation of enzymatic substances, which are acidic metabolites, resulting from inhibition of such enzymes causing chilling injury symptoms. Most of these intermediates are acidic, so if the acidity level is high for fruit, this indicates for fruit chilling injury, also storage at low temperatures causes in declining ascorbic acid content. However, Biswas et al. (2015) describe that, one possible effect of intermittent warming is to restore metabolite concentrations, which in turn occurs through allowing tissues to activate synthetic compounds and appropriate metabolic enzymes at an unprecedented rate during

chilling, thus allowing tissues to recover depleted substances, the tissues can catabolism the excess intermediate material accumulated during chilling; and allowing tissues to synthesize new compounds. Also, Alex et al. (2019) noted that, tissue warming and cooling (IW) maintains a high level of phospholipids, and increases the degree of fatty acid unsaturation,

The increase in electrolyte leakage in the fruit pulp was associated with a decrease in pulp firmness as was clearly associated with tissues affected by chilling damage (Panida and Suriyan 2017) where the chilling injury caused cell membrane dysfunction in plant tissues (Raimbault et al., 2011). Moreover, loss of electrolytes from tissues during cold storage leads to damage to cell membranes due to increased electrolyte leakage. (Yanli, et al., 2019). The results showed a delay of increased electrolyte leakage in the tissues of chilled fruits by external application of MeJA. Demei et al. (2012) on *Agaricus bisporus*, Fan et al. (2016) on *Solanum melongena*, Panida and Suriyan (2017) on Pineapple fruit and Wang et al. (2019) on bell pepper. While IW reduces CI by preserving the integrity of cell membranes, warming of cooled tissues for short periods helps in repair damage to membranes and metabolic pathways. (Alex et al., 2019)

Physiological attributes

Respiration rate (mg CO₂/kg fresh fruits /hr.)

It is clear from data in Table 6 that respiration rate of both Palmer and Sensation mango cvs. greatly affected with different applied treatments during 2018 and 2019 seasons. However, all applied treatments except 2.0 mM MeJA treatment were effective in minimizing fruit respiration rate than control after exposing the fruits to two storage stage (15 days at 5 ± 1°C and 7 days, at 20± 2°C). The treatment of 1.0 mM MeJA plus IW was more effective than other treatments in recording less fruit respiration rate than other treatments either in both mango cvs or the two studied seasons . Generally, Sensation mango cv. produced less respiration rate value than Palmer regardless of the used treatments which means that Sensation mangos hah a good storability than Palmer mangos.

Ethylene production (µl C₂H₄/Kg fruit/hr.)

As it previously finding and discussed on respiration rate , it is clear from data in Table 6 that all applied treatments greatly increased the rate of ethylene production than control except the treatment of 2.0 mM MeJA which was similar

or less than control. It could be concluded that this treatments caused a general reduction in ethylene production than other treatments which means that this fruits failure in ripening . Palmer mangoes recorded the less values of ethylene production than Sensation mango with the worth treatments. Consequently, Palmer mango cv. was not capable of promoting ethylene production by storage temperatures, which cause chilling injury. The high ethylene production values were recorded by 0.5 mM MeJA + IW, 1.0 mM MeJA and 1.0 mM MeJA+IW with slight differences among them , in both mango cvs. in both seasons. However, Sensation mango cv. produced less ethylene values than Palmer mangos regardless of the used treatments and this finding means that Sensation mangos had a good tolerance to storage either cold storage or ripening phase . It is well known that as ethylene production decreased fruit life and storability are increased especially in climacteric fruit such as mangos.

Catalase enzyme activity (as µmol min⁻¹ mg⁻¹ protein.)

Data tabulated in Table 6 showed the effect of intermittent warming and methyl jasmonate and their combination on catalase enzyme activity of two mango cvs. after finished from cold storage and repining durations in two studied seasons. Generally, all applied treatments greatly increased catalase enzyme activity than control except the treatment of 2.0 mM MeJA which recorded less values of catalase enzyme activity. The highest values of catalase enzyme activity (0.64 and 0.69 µmol min⁻¹ mg⁻¹ protein in first season of Palmer and Sensation mango cvs, respectively) were recorded by 1.0 mM MeJA + IW. The same findings were recorded for the two mango cvs in both studied seasons. The increased of catalase enzyme activity due to the applied treatments means that the studied treatments were effective in increasing storability of mango either during cold storage or during ripening periods .Additionally , Sensation mango exhibited higher values of catalase enzyme activity than Palmer mango regardless of the used treatments.

Peroxidase enzyme activity (as µmol min⁻¹ mg⁻¹ protein.)

It is evident from data in Table 6 that peroxidase enzyme activity followed similar trend to those found in catalase enzyme activity. However, values of peroxidase enzyme activity were higher than values of catalase enzyme activity. An evident increase in peroxidase enzyme

activity due to applied treatments than control except the treatment of 2.0 mM MeJA recorded less value than control. The highest values of peroxidase enzyme activity were recorded by the treatment of 1.0 mM MeJA + IW in both studied seasons and both mango cvs,.. The same findings were recorded for the two mango cvs in both studied seasons. However, Sensation mango

cv. recorded high values of peroxidase enzyme activity than Palmer mango cv, regardless of the used treatments. As it mentioned in catalase enzyme activity, the increase in peroxidase enzyme activity as result of applied treatments are parallel with increase of storability of mango fruits.

TABLE 6. Effect of intermittent warming and methyl jasmonate treatments on respiration rate $\text{mg CO}_2 \text{ Kg}^{-1}$ (fr. wt.) h^{-1} , ethylene production $\mu\text{LC}_2\text{H}_4 \text{ Kg}^{-1}$ (fr. wt.) h^{-1} , catalase and Peroxidase enzymes activities ($\mu\text{mol min}^{-1} \text{ mg}^{-1}$ protein) of two mango cvs. after finished of storage phase and way out fruits from ripening room during 2018 and 2019 seasons.

Treatments	After finished of storage durations (15 Days in cold storage at 5 ± 1 followed by 7 days at $20\pm 2^\circ \text{C}$)							
	Respiration rate $\text{mg CO}_2 \text{ Kg}^{-1}$ (fr. wt.) h^{-1}		Ethylene production $\mu\text{LC}_2\text{H}_4 \text{ Kg}^{-1}$ (fr. wt.) h^{-1}		Catalase enzyme active ($\mu\text{mol min}^{-1} \text{ mg}^{-1}$ protein)		Peroxidase enzyme active ($\mu\text{mol min}^{-1} \text{ mg}^{-1}$ protein)	
	Palmer	Sensation	Palmer	Sensation	Palmer	Sensation	Palmer	Sensation
Season 2018								
Control	94.3 ab	83.1 ab	1.35 e	1.57 e	0.23 e	0.28 de	7.5 ef	9.7 ef
I.W	86.4 c	80.3 b	1.68 cd	1.83 cd	0.32 d	0.35 d	11.0 d	14.4 d
0.5 mM MeJA	84.6 c	74.4 cd	1.87 c	1.90 c	0.43 c	0.49 c	14.3 c	17.6 c
0.5 mM MeJA + I.W	78.6 d	69.8 d	2.17 b	2.03 bc	0.52 b	0.57 b	17.6 b	23.1 ab
1.0 mM MeJA	77.5 d	70.6 d	2.33 ab	2.11 ab	0.51 b	0.57 b	16.8 b	20.8 b
1.0 mM MeJA + I.W	71.2 e	64.8 e	2.46 a	2.28 a	0.64 a	0.69 a	20.3 a	25.2 a
2.0 mM MeJA	97.5 a	89.8 a	1.29 e	1.44 e	0.20 e	0.23 e	6.4 f	7.7 f
2.0 mM MeJA + I.W	90.3 bc	78.9 bc	1.58 d	1.76 d	0.27 de	0.32 d	9.9 de	12.0 de
Season 2019								
Control	93.1 b	88.7 ab	1.53 e	1.74 de	0.20 d	0.24 e	9.3 d	8.5 f
I.W	85.1 c	82.4 bc	1.69 de	1.91 cd	0.27 cd	0.38 d	10.7 d	14.9 d
0.5 mM MeJA	82.2 cd	77.2 cd	1.96 c	2.10 bc	0.34 c	0.47 c	15.1 c	20.5 c
0.5 mM MeJA + I.W	74.2 ef	66.1 e	2.27 b	2.14 ab	0.51 b	0.69 b	17.7 b	23.8 a
1.0 mM MeJA	76.3 de	73.8 d	2.24 b	2.19 ab	0.44 b	0.62 b	20.0 ab	21.1 bc
1.0 mM MeJA + I.W	69.6 f	60.4 e	2.52 a	2.34 a	0.62 a	0.77 a	21.6 a	23.0 ab
2.0 mM MeJA	106.5 a	92.8 a	1.48 e	1.61 e	0.22 d	0.21 e	6.1 e	7.0 f
2.0 mM MeJA + I.W	91.7 b	84.4 b	1.78 cd	1.82 d	0.23 d	0.42 cd	8.6 dd	11.6 e

Values followed by the same letter (s) are not significantly different at 5% level

Initial sample:-

Respiration rate $\text{mg CO}_2 \text{ Kg}^{-1}$ (fr. wt.) h^{-1} recorded (29.4 and 32.1, for Palmer cv.) & (25.0 and 26.7 for Sensation cv.) during 2018 and 2019 seasons.

Ethylene production $\mu\text{LC}_2\text{H}_4 \text{ Kg}^{-1}$ (fr. wt.) h^{-1} recorded (0.63 and 0.67, for Palmer cv.) & (0.54 and 0.59 for Sensation cv.) during 2018 and 2019 seasons.

Catalase enzyme ($\mu\text{mol min}^{-1} \text{ mg}^{-1}$ protein) recorded (0.22 and 0.26, for Palmer cv.) & (0.27 and 0.25 for Sensation cv.) during 2018 and 2019 seasons.

Peroxidase enzyme ($\mu\text{mol min}^{-1} \text{ mg}^{-1}$ protein) recorded (7.7 and 6.3, for Palmer cv.) & (9.1 and 8.0 for Sensation cv.) during 2018 and 2019 seasons.

Low temperature affects ethylene, production and action which leads to delayed production of ethylene in fruits, and thus irregular ripening occurs in fruits. (Kondo et al., 2007). However, Artes et al. (1998) found that, an increase in temperature (IW) allows the fruit to ripen and release some toxic substances that have cumulative during cold storage. as well as Biswas et al. (2015) stated that, intermittent warming stimulated production. The ethylene in fruit during times of warming. The catalyzed ethylene during IW may contribute to enabling full red development after storage at lower temperatures and induction of cold tolerance through increased ripening. Moreover, (Porat et al. 2003 and Xi et al. 2012) they found that, IW significantly reduces the incidence and intensity of Caries for all chilled fruits with or without ethylene stimulation, indicating a more direct effect of IW on CI-related decomposition.

A sharp decrease in the respiration rate of chilling-sensitive fruits was observed, unlike non-sensitive fruits. (Safizadeh, et al., 2007). Moreover, Wang et al. (2019) indicated that, the rate of oxidation associated with the decomposition of sugar, which may lead to the accumulation of respiratory intermediates to toxic levels or fermentation, which causes the occurrence of chilling injury development.

A great effect on methyl jasmonate was observed by (Perez et al., 1997) exogenous application of MJ significantly increased ethylene production at full and semi-mature fruits, as MJ plays a role in fruit ripening by stimulating ethylene biosynthesis. Besides, Demei et al. (2012) indicated that, the lower concentration of exogenous MJ stimulated the production of ethylene, while the high concentrations inhibited the production of ethylene. Explained, Kondo et al. (2007) noticed an increase in ethylene production in MJ-treated fruits due to increased activity of enzymes involved in ethylene biosynthesis as results showed increased ACC oxidase and ACC synthase activity in MJ-treated fruits compared to untreated fruits. Also, Zhang et al. (2016) showed that, production of carbon dioxide decreased with jasmonate treatments.

The evidence in a study by Cao et al. (2009) indicated a positive association between cooling tolerance in post-harvest horticultural crops and higher activities of catalase and peroxidase.

Likewise (Jin et al., 2006) demonstrated that, the MeJA treatment stimulated the antioxidant enzymes, such as SOD activity and ascorbate peroxidase activity and inhibited the development of chilling symptoms. It is widely accepted that MeJA treatment prompt defense responses in cold-stressed vegetables and fruits, as the onset of chilling tolerance is often associated with the production of antioxidant enzymes and bioactive compounds. In addition, Ding et al. (2002) decided that, MeJA treatment induced SOD activity, which has a membrane-protecting function through the enhanced activities of antioxidant enzymes

Conclusion

Based on the previous results, it could be recommend that immersing the mango fruits in MeJA at 1.0 mM with regular exposure every three days at 20 °C for 8 hr. and storing at 5 ± 1°C for 15 days followed by a fruit ripening at 20± 2 °C for 7 days is an effective way to maintain quality and relieve symptoms of chilling injury, avoid membrane damage and enhance some of the bioactive compounds (antioxidant enzymes activity and ethylene production) especially Sensation mango cultivar.

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Conflicts of interest

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تطبيق التدفئة المتقطعة والميثيل جاسمونات لتجنب حساسية أضرار البرودة لصنفي المانجو البالم
والسنسيشن تحت ظروف المخزن المبرد

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تعتبر ثمار المانجوم الثمار الحساسة لأضرار البرودة عند تخزينها في درجة حرارة أقل من ١٠ درجة مئوية والتي تحدث تلون قشرة الثمرة باللون البني و تنقر في السطح مع زيادة القابلية للأعفان ثم فشل أو عدم انتظام النضج وأخيرا إنخفاض حاد في جودة الثمرة. لهذا كان هدف هذا البحث هو دراسة تطبيقا لتدفئة المتقطعة واستخدام مادة الميثيل جاسمونات بتركيزات مختلفة للتخفيف من حدة الأصابة بأضرار البرودة لصنفي المانجو البالم والسنسيشن خلال موسمي ٢٠١٨ و ٢٠١٩.

أوضحت النتائج المتحصل عليها ان جميع تركيزات مادة الميثيل جاسمونات (ما عدا التركيز العالي) مع التدفئة المتقطعة حسنت كثيرا من صفات الجودة وكان أفضل الأثر مع تركيز ١,٠ ملليمول جاسمونات الميثيل مع التدفئة المتقطعة لكلا من فترتي التخزين (تخزين بارد لمدة ١٥ يوم علي ١٠+٥ °م ثم إنضاج الثمار لمدة ٧ ايام علي ٢٠ °م مع صنفي المانجو والتي قللت كثيرا من نسبة الثمار المستبعدة وأعراض أضرار البرودة كما قللت من الفقد في الوزن ومعدل فقد صلابة اللحم . كذلك فإن الثمار التي تم معاملتها بـ ١,٠ ملليمول ميثيل جاسمونات معالتدفئة المتقطعة أنقصت معدل التسرب الأيوني والحموضة الكلية وزادت قيمة حمض الأسكوربيك ونسبة المواد الصلبة الذائبة الكلية والمحتوي الكلي من الصبغات في القشرة واللحم (الكاروتينات - الأنثوسيانين). كذلك لوحظ فروق معنوية واضحة في النشاط الإنزيمي - إنتاج الإيثيلين ومعدل التنفس في أنسجة اللحم من الثمار المعاملة والمقارنة . وكانت المعاملة ١,٠ ملليمول جاسمونات الميثيل + التدفئة المتقطعة والتي تعتبر معاملة مثلي قد عملت علي زيادة معدل نشاط إنزيمي البيروكسيديز والكتاليز والذي يحدث أثناء التخزين المبرد كذلك نقص معدل التنفس وتنشيط إنتاج الإيثيلين. وقد اوضحت النتائج أن صنف المانجو سنسيشن ذو قدرة تخزينية وفترة تداول أفضل من صنف المانجو البالم.

الكلمات الدالة: التدفئة المتقطعة، ميثيل جاسمونات، اضرار البرودة، التخزين المبرد، مانجو بالم، مانجو سنسيشن.