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EFFECT OF CERTAIN POSTHARVEST TREATMENTS ON THE ANTHRACNOSE DISEASE INFECTING MANGO FRUITS

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ABSTRACT: The present work aimed to evaluate capability of certain acids and oils as postharvest treatments to induce resistance of "Kiett" mango fruits against *Colletotrichum gloeosporioides in vitro* and *in vivo.* Therefore, essential oils like Thyme and Cinnamon, and certain acids such as Salicylic and Boric have been tested to evaluate their effects on fruit deterioration of mango post harvest quality. Results indicated that Thyme oil showed the highest efficacy in inhibiting fungal growth followed by Cinnamon oil giving inhibition percentage of 77.8 and 61% for both oils respectively, at their concentrations of 10000 ppm while both Salicylic and Boric acids caused complete mycelial growth inhibition at their concentration of 500, 3000ppm, respectively. On the other side, decay incidence of mango fruits treated with Thyme oil or Cinnamon oil were significantly than the other treatments either naturally or artificially infected with fungi. The lowest values of weight loss percentage were resulted from Thyme oil treatment of naturally infected fruits, while for artificially infected fruits, the Cinnamon oil treatment caused the lowest ones in two seasons. Moreover, postharvest treatments with Thyme oil or Cinnamon oil of mango fruits either naturally or artificially infected with fungi significantly decreased change rate of fruit colour that means delayed fruit ripening in comparison with the other treatments and control fruits. In addition, these treatments significantly decreased the deterioration rate of fruit contents of total soluble solids (TSS), titratable acidity (TA), total phenol contents (TPC) and polyphenol oxidase (PPO) compared with the other treatments and control. In conclusion, it could be concluded that postharvest treatments of mango fruits with Thyme or Cinnamon oils at 10000 ppm can be an effective method in order to increase "Kiett" mango fruit storability and keep fruit quality during storage.

Key words: Mango - Postharvest - Anthracnose- Essential oils and acids.

INTRODUCTION

Mango fruit has an appreciated nutrition value and good taste and is widely spread all over the tropics and subtropics regions worldwide. It is considered as a major tropical export fruit that is cultivated in many countries **(Chen *et al*., 2014).** In various cultivated areas, the mango trees and their fruit crop are affected by certain serious diseases including the anthracnose. The anthracnose is one of the most destructive and dangerous disease that occur during flowering and fruiting stages of mango at rainy areas and caused by the fungus *Colletotrichum gloeosporioides* **(Pitkethley and Conde, 2007)**. The disease symptoms include flower blight, fruit rot, and leaf spots **(Arauz, 2000).** The damage is identified by destruction of the complete inflorescence, leading to the absence of fruit setting. This disease leave infected young fruits with black spots, shriveling, and ultimately drop off of many fruitlets. In addition, infected mature fruits are responsible for high losses during storage, transportation and marketing (**Abd- Alla and Wafaa, 2011).** Synthetic fungicides application is the main approach for controlling diseases of mango fruit such as anthracnose effectively, **(Kim *et al.*, 2007).** Nevertheless, massive application of high concentrated can leads to emergence of pathogen resistance toward the applied fungicide **(Tian, 2006)** add to that the undesirable environmental effects of the fungicide residues which urge scientist to find new and more safe technologies for controlling different fruit diseases **(Junyu *et al.*, 2017).** As no fungicides were registered for postharvest disease to control mango fruit diseases, including the anthracnose, additionally, the raising of environmental concern to the massive use of fungicides has led to continuous search for alternatives that include safe and environmentally accepted agents and to be regularly tested and evaluated for different diseases control. Therefore, the present study aimed to investigate *in vitro* efficacy of certain oils and acids to suppress the pathogenic fungus *Colletotrichum gloeosporioide* and also to evaluate their effects under cold storage conditions.

MATERIALS AND METHODS

This work was carried out during the two successive years 2020 and 2021 on the Keitt mango (*Mangifera indica*) var. Kiett cultivated in a privet orchard at Sharkia Governorate, Egypt. Harvested mango fruits were immediately transported to fruit handling department and sound fruits were selected on the basis of uniformity of size and color, then separated into naturally infected fruits group and artificially infected fruits group. Finally, each group included five treatments as follows:

1- Fruits treated with Salicylic acid at 500 ppm for 2 min.

2- Fruits treated with Boric acid at 3000 ppm for 2 min.

3- Fruits treated with Cinnamon oil at 10000 ppm for 2 min.

4- Fruits treated with Thyme oil at 10000 ppm for 2 min.

5- Control (untreated fruits).

Pathogen isolation

The fungi *C. gloeosporioides* was obtained from naturally infected mango CV. (Keitt) fruits stored in a commercial cold room at Behaira governorate. Small pieces of infected mango fruit were prepared and externally sterilized by 2% sodium hypochlorite for 2 min followed by rinsing 3 times by sterilized distilled water (SDW) and finally, placed on Potato Dextrose Agar (PDA) and incubated at 25 °C. Koch's postulates were effectuated for the causal pathogen identity confirmation. Finally, conidia of 7-day-old pure cultures were used for inoculations, and sub-culturing was carried out at 7-day intervals.

In vitro assay

The effect of different essential oil and acids on *Colletotrichum gloeosporioides* linear growth (cm) was investigated using poisoned food technique **(Anand *et al*., 2016; Abd-Alla and Haggag, 2013 and Quiróz-López *et al*., 2021)**. The tested prepared serial concentrations were 1, 0.5, 0.25 and 0.125 % for essential oils, 1000, 2000, 3000, 4000 and 5000 ppm for Boric acid and 50, 100, 200, 300, 400 and 500 ppm for Salicylic acid. Each concentration was added to worm (45-55°C) sterile PDA medium before its solidification under aseptic conditions. Each petri plates were centrally inoculated with 5-mm discs of periphery 7day old cultures of *C. gloeosporioides* isolate. For control treatment, plain medium was inoculated with fungus discs. For each tested concentration and the control, three replicates (three petri dishes) were inoculated then incubated at 22°C for 7 days. Average linear growth for each treatment's replicates was calculated and expressed in centimetre (cm). Based on preliminary tests, effective concentration that inhibits *C. gloeosporioides* linear growth was selected.

Fruits destined to artificial inoculation were surface sterilized using 70 % alcohol for 2 min followed by 2 % Sodium hypochloride for 10 seconds and finally washed thoroughly with SDW for 1 min **(Moreira and Mio, 2007)**. Surface sterilized fruits were air dried at room temperature then each fruit was punctured for a depth of 2 mm at the middle of its side with a stainless-steel rod of 2-mm in diameter. Treated fruits were air dried at room temperature under aseptic conditions for 24 hours then inoculated with a conidial suspension of *C. gloeosporioides* (10^5 conidia /mL) for 30 seconds while non-treated (control) fruits were prepared as above then punctured then treated with SDW water containing Triton X. Finally, all treatments were packed in carton boxes in one layer. For each treatment, three boxes (15 fruits/ box) were used and stored at 13±1°C and 90% relative humidity (RH) for five weeks. The fruits' physical and chemical properties changes were weekly evaluated from the beginning to the storage period end.

Disease assessment

Disease incidence (%): The disease incidence was calculated for each replicate by relating decayed diseased fruits to the total number of fruits.

The Disease severity rating scale was applied to assess disease severity in different mango according to **Lakshmi *et al*. (2011)** and calculated as follows:

Disease severity = ∑decayed area (%) of each fruit X 100/ No. of fruits of each replicate and decayed area (%) for each single fruit was determined as periods.

Rating	Meaning
0	No infection
1	Up to 5% of fruit surface area covered
2	6-10% of fruit area affected
3	between 11 and 20% of fruit area covered
4	21-50% of fruit area affected
5	more than 50% of the fruit surface area covered

Physical characteristics

Fruit weight loss percentage (FWL %)

The equation stated below was applied to determine the weight loss percentage:

FWL% = [(Wi –Ws)/ Wi] x100

Where, Wi = fruit weight at initial period.

Ws = fruit weight at sampling period**.**

Fruit Firmness (Kg/cm^2): Fruit firmness was determined as Kg/cm^2 by using fruit pressure tester mod. FT 327 (3-27 Lbs).

Fruit color: Lightness (L*) and hue angle (h°) were estimated using Minolta Calorimeter (Minolta Co. Ltd., Osaka, Japan) according to (**Mc Guire, 1992**).

Chemical Properties

Total soluble solids (TSS): Percentage of TSS was determined in mango juice using Digital refractometer PR32 (0.32% Atago Palete ATago. CO. LTD. Japan).

Titratable acidity (TA): Percentage of TA was recorded by titrating the juice against 0.1 N sodium hydroxide using phenolphthalein indicators and expressed as percentage of citric acid according to **(A.O.A.C., 2005)**.

Total phenolic content (TPC): TPC in juice was determined using the Folin-Ciocalteu method **(Meighani *et al*., 2014)** was expressed as (mg gallic acid /100 mL juice).

Polyphenol oxidase activity (PPO,Ug /FW)**:** it was measured as mentioned by **y (Matta and Diamond, 1963)**The reaction mixture contains 1ml of the crude enzyme + 1ml phosphate buffer solution (7.1pH) + 1ml catechol and completed with distilled water to 6.0 ml. Polyphenol oxidase was expressed as the change in the absorbance of the mixture every 0.5 minute for 5 minutes period at 495 nm by Spectrophotometer. Unit (U) of PPO activity was defined as 1.0 increase in absorbance at 495 nm / min / g FW.

Statistical analysis

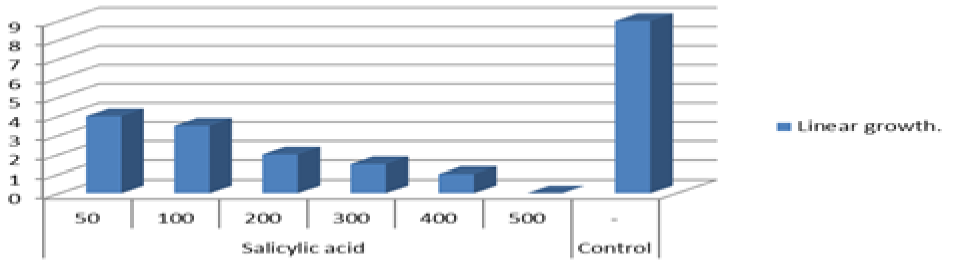
A randomized complete design was used, and the statistical analysis was carried out according to **(Snedecor and Cochran, 1990)** and means were compared by Duncan's multiple range tests at the 5 % level of probability.

RESULTS

Effect of Salicylic acid (SA) **on linear growth of C. *gloeosporioides***

In vitro test, the effect of Salicylic acid on linear growth of C. *gloeosporioides* showed that all tested SA concentrations higher than 50 ppm has significantly inhibited *C. gloeosporioides* mycelial growth as shown in Fig. (1), and at 500 ppm has completely inhibited the growth of *C. gloeosporioides*.

Fig.1 Effect of salicylic acid on linear growth of *Colletotrichum gloeosporioides*.



Effect of Boric acid (BA) on linear growth of *C. gloeosporioides*

As shown in Fig. (2), *In vitro* test, the effect of Boric acid on linear growth (cm) on C. *gloeosporioides* as a response of increasing their concentrations in series from 1000 ppm to 5000 ppm. The BA at 3000ppm has caused complete inhibition of linear growth compared to control.

Activity of two essential oils on mycelial growth of *C. gloeosporioides*

Concerning the mycelial growth of the studied pathogenic fungus, Thyme oil showed the highest efficacy in inhibiting it followed by Cinnamon oil, giving inhibition percentage of 77.8 and 61% for both oil respectively at their concentrations of 10000ppm (Fig.3). In addition, the mycelial growth inhibition percentage was directly proportional with the tested essential oils concentrations.

Fig .2 Effect of boric acid on linear growth of *Colletotrichum gloeosporioides*

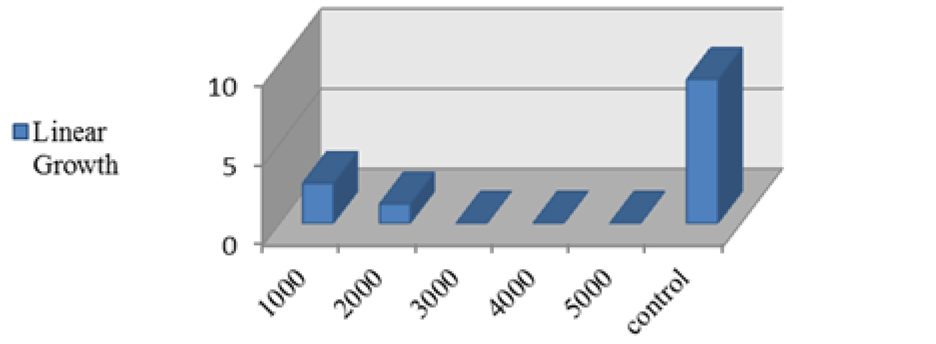
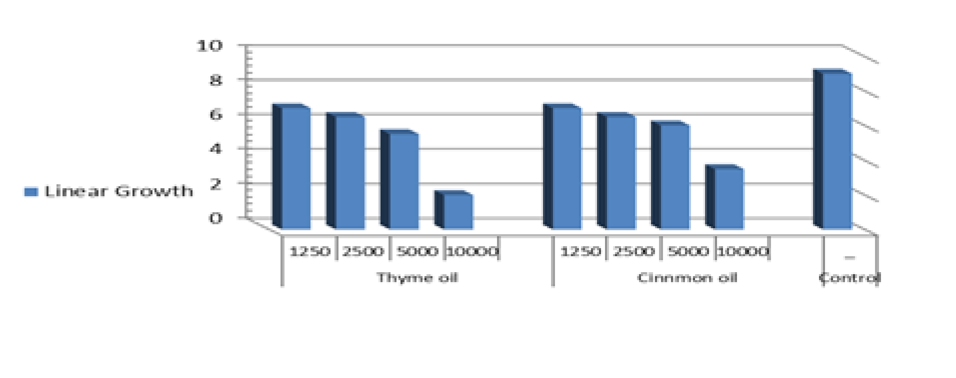


Fig.3 Effect of Thyme and Cinnmon Oil on linear growth of Colletotrichum gloeosporioides



Effect of postharvest treatments with essential oils and certain acids on Anthracnose disease of "Kiett" mango

Postharvest treatments of naturally infected mango fruits with essential oils and certain acids during seasons 2020/21 resulted in significant control of anthracnose disease incidence and severity during cold storage at 13°C for 3 weeks and prolonged storage period to 5 weeks at 13°C. While in artificially infected fruits, the control treatment showed 100% disease incidence and 57.3% and 56% of disease severity in the two seasons, respectively. Regarding the artificially infected fruits, also Salicylic acid, Boric acids, Cinnamon oil, and Thyme oil completely inhibited Anthracnose disease incidence and severity for the first two weeks, while after these two weeks, only Cinnamon oil and Thyme oil resulted in significantly reduction for the anthracnose disease incidence and severity comparing to the control up to five weeks. (Tables 1, 2, 3 & 4).

Table (1). Effect of some postharvest treatments on disease incidence (DI) and severity (DS) of naturally infected mango fruits with *Colletotrichum gloeosporioides* during the season 2020

Treatments	Decay (%) during cold storage at 13ºC									
	Season 2020									
	1week		2week		3 week		4 week		5 week	
	DI*	DS**	DI	DS	DI	DS	DI	DS	DI	DS
Salicylic acid	0.0	0.0	0.0	0.0	0.0	0.0	13.3	2.7	26.7	5.3
Boric acid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.7	6.7
Cinnamon oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thyme oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Control	0.0	0.0	13.3	2.7	20	6.7	26.7	13.3	33.3	20.0
LSD.0.5%	-	-	1.8	0.2	1.2	1.7	1.7	0.9	2.2	0.9

Table (2). Effect of some postharvest treatments on disease incidence (DI) and severity (DS) of artificially infected mango fruits with *Colletotrichum gloeosporioides* during the season 2020

Treatments	Decay (%) during cold storage at 13ºC									
	Season 2020									
	1week		2week		3 week		4 week		5 week	
	DI*	DS**	DI	DS	DI	DS	DI	DS	DI	DS
Salicylic acid	0.0	0.0	0.0	0.0	6.7	1.3	13.3	5.3	26.7	13.3
Boric acid	0.0	0.0	0.0	0.0	0.0	0.0	6.7	1.3	40	13.3
Cinnamon oil	0.0	0.0	0.0	0.0	0.0	0.0	6.7	1.3	13.3	2.7
Thyme oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	5.3
Control	0.0	0.0	20	8.0	26.7	10.7	33.3	26.7	100	57.3
LSD.0.5%	-	-	1.6	0.9	1.7	1.0	1.9	1.5	3.5	0.8

Table (3). Effect of some postharvest treatments on disease incidence (DI) and severity (DS) of naturally infected mango fruits with *Colletotrichum gloeosporioides* during the season 2021

Treatments	Decay (%) during cold storage at 13ºC									
	Season 2021									
	1week		2week		3 week		4 week		5 week	
	DI*	DS**	DI	DS	DI	DS	DI	DS	DI	DS
Salicylic acid	0.0	0.0	0.0	0.0	6.7	1.3	13.3	1.3	20	16
Boric acid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.7	21.3
Cinnamon oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thyme oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Control	0.0	0.0	6.7	1.3	13.3	2.7	20	12	26.7	16
LSD.0.5%	-	-	0.7	0.2	1.1	0.3	1.3	1.2	1.7	0.5

Table (4). Effect of some post-harvest treatments on disease incidence (DI) and severity (DS) of artificially infected mango fruits with *Colletotrichum gloeosporioides* during the season 2021

Treatments	Decay (%) during cold storage at 13ºC									
	Season 2021									
	1week		2week		3 week		4 week		5 week	
	DI*	DS**	DI	DS	DI	DS	DI	DS	DI	DS
Salicylic acid	0.0	0.0	0.0	0.0	0.0	0.0	13.3	1.3	26.7	22.7
Boric acid	0.0	0.0	0.0	0.0	0.0	0.0	6.7	1.3	40	13.3
Cinnamon oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	2.7
Thyme oil	0.0	0.0	0.0	0.0	0.0	0.0	6.7	1.3	20	4.0
Control	0.0	0.0	13.3	5.3	20	8.0	33.3	11.3	100	56
LSD.0.5%	-	-	0.9	0.65	1.1	0.7	2.2	2.0	3.9	0.9

Fig. (4). (A) shows naturally infected fruits with no treatment (control) at the left side and after 5 weeks post treatment with Thyme oil at the right side. (B) Shows naturally infected fruits with no treatment (control) at the left side and after 5 weeks post treatment with Cinnamon oil at the right side.

Physical characteristics

Weight loss percentage (%)

Data in Fig (5) shows that in natural and artificial infection, weight loss percentage was gradually and significantly increased with the increasing of the storage period in both seasons of study.

At the end of storage periods, untreated fruits exhibited high significant weight loss percentage compared to all treatments of natural and artificial infections in both. Contrary, lowest values of weight loss percentage was resulted from treatment of naturally infected fruits by Thyme oil, and treatment of artificially infected fruits with Cinnamon oil in two seasons.

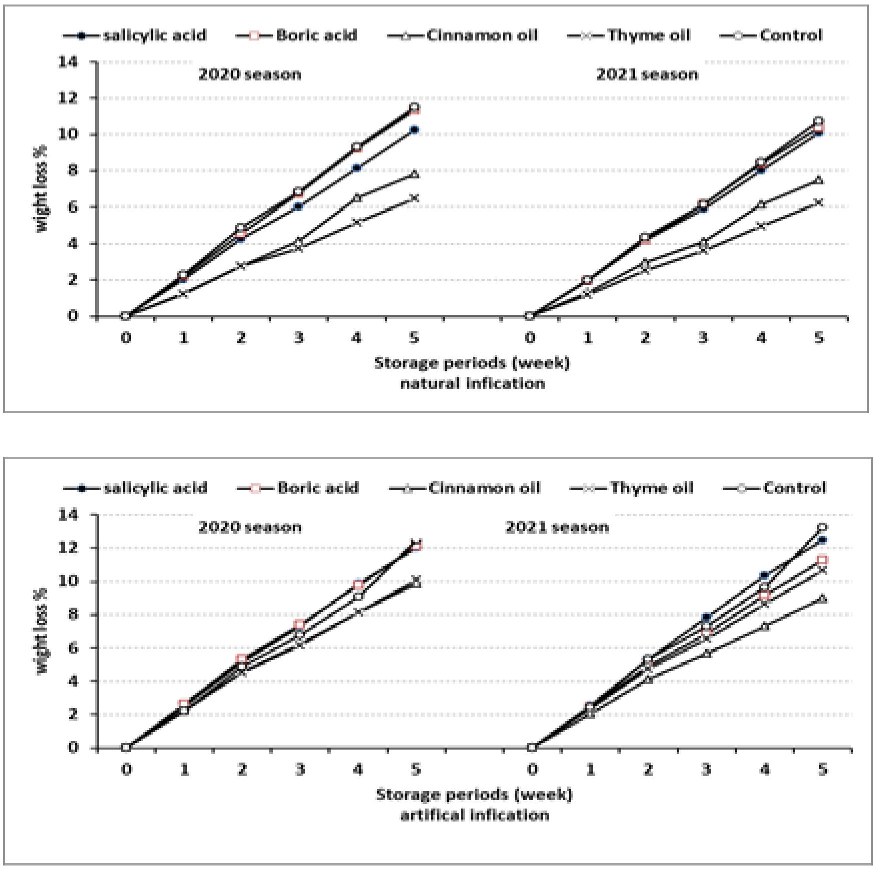
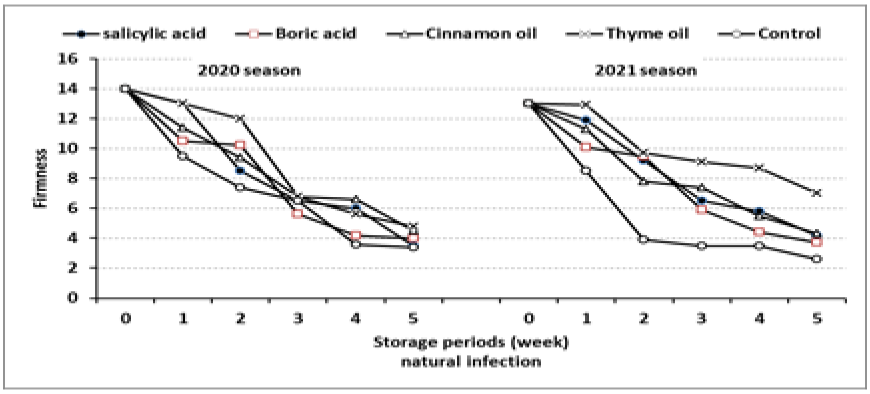


Fig. (5). Effect of some post-harvest treatments on weight loss percentage of naturally and artificially mango fruits infected with *Colletotrichum gloeosporioides* during 2020 and 2021 seasons.

Fruit firmness (Kg/cm^2)

Showed data in Fig. (6) indicated that, fruit firmness of natural and artificial infection gradually and significantly decreased with prolonging of storage period during the two seasons, all treatments maintaining firmness compared to control treatment.

At the end of storage period, fruits treated with Thyme oil gave the highest fruit firmness during the 1st and 2nd seasons, compared to non-treated fruits (control) treatment that exhibited the lowest values during the first and second seasons for both natural and artificial infections.



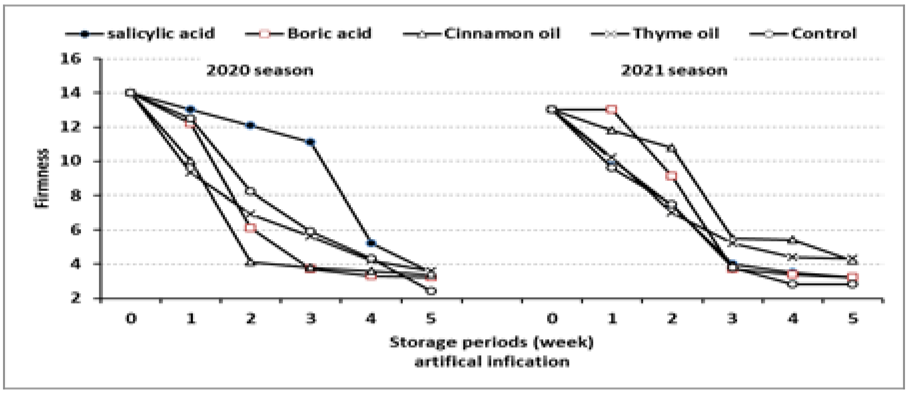
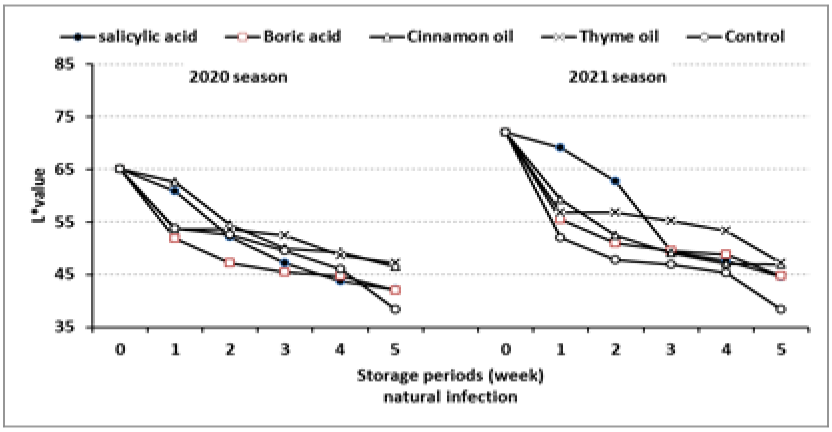


Fig. (6). Effect of some post-harvest treatments on firmness (Kg /cm^2) of naturally and artificially mango fruits infected with *Colletotrichum gloeosporioides* during 2020 and 2021 seasons.

Fruit color

Lightness (L*)

Results in Fig.7 cleared that external lightness (L*) in natural and artificial infections was gradually decreased by expanding of the storage period. At the end of storage period, Thyme oil treatments gave the highest values of L* in the first and second seasons without significant differences and control treatment exhibited the lowest value of L*.



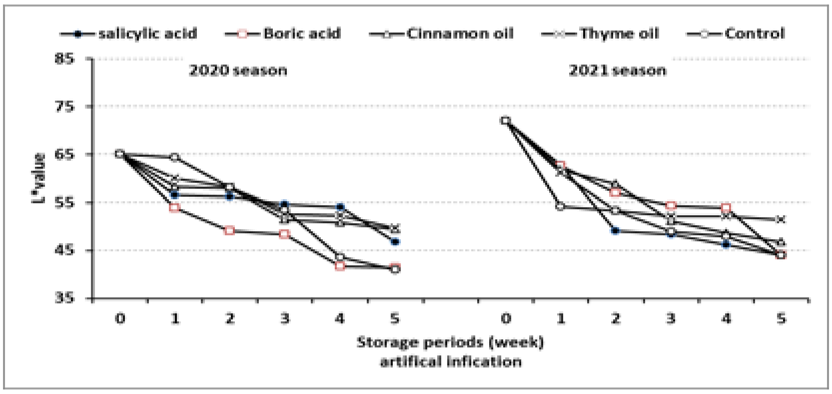


Fig. (7). Effect of some post-harvest treatments on L* of naturally and artificially mango fruits infected with Colletotrichum gloeosporioides during 2020 and 2021 seasons.

Hue angle (hº value)

Results in Fig (8) clarified that skin color expressed as hue angle (hº) for naturally and artificially infected fruits were decreased (increase density of yellow color) with the advance in cold storage period and significant differences between all treatments were observed in both seasons by the end of storage period. Thyme oil fruits treatment gave the highest value of hº in the two seasons and the lowest values were recorded for control fruits in both seasons.

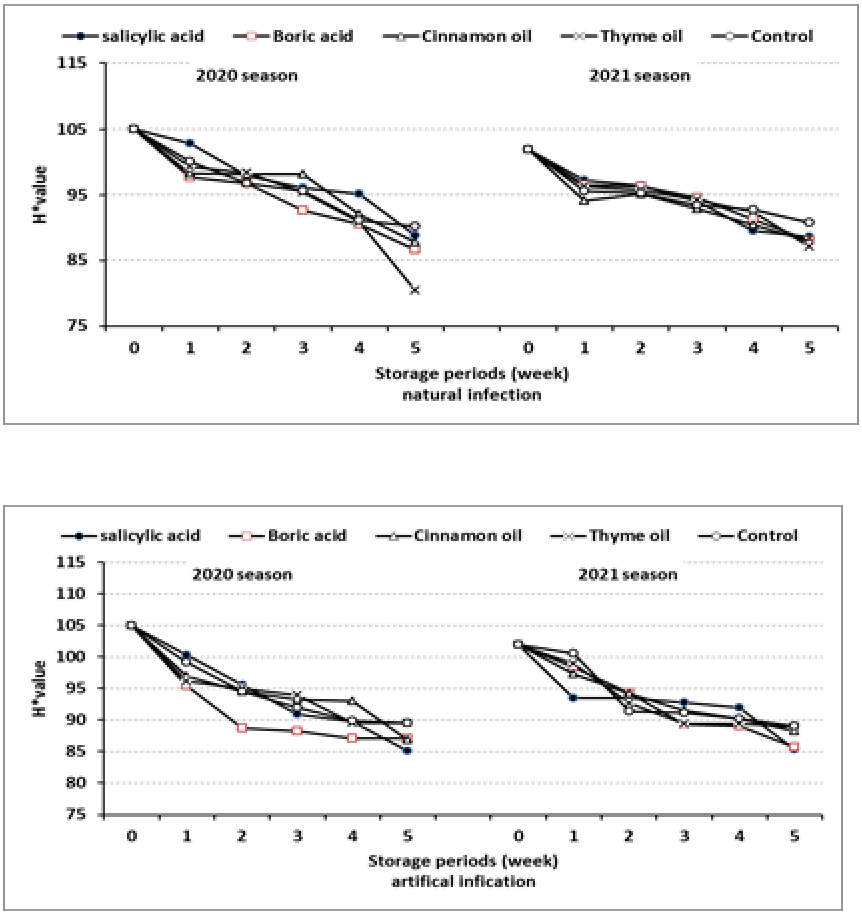
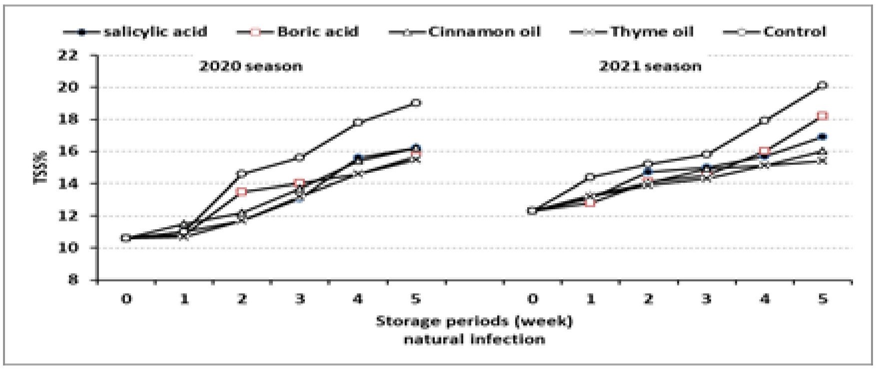


Fig. (8). Effect of some post-harvest treatments on H* of naturally and artificially mango fruits infected with *Colletotrichum gloeosporioides* during 2020 and 2021 seasons.

Chemical properties

Total Soluble solid percentage (TSS %)

The data showed in Fig 9 indicate that total soluble solid contents of Mango fruits "var. Keitt" gradually and significantly increased with the advance in cold storage periods during the two seasons. Data also cleared that, total soluble solid contents of fruits treated with Thyme oil gave lowest values in the two seasons compared with the other treatments. On contrast, untreated fruits of both naturally or artificially infection showed the highest percentage of TSS contents in the both seasons.



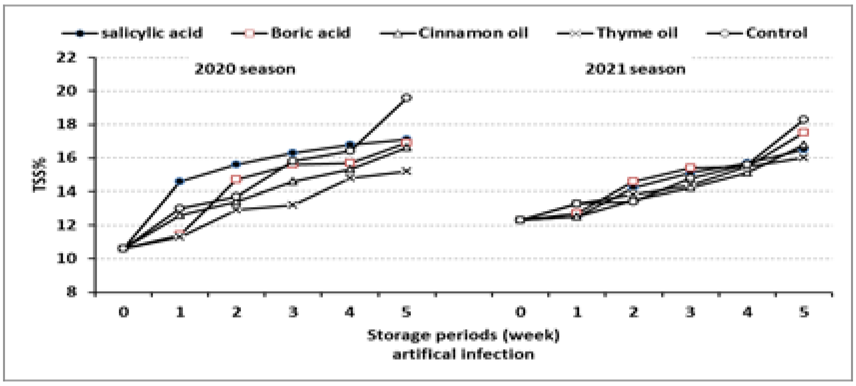
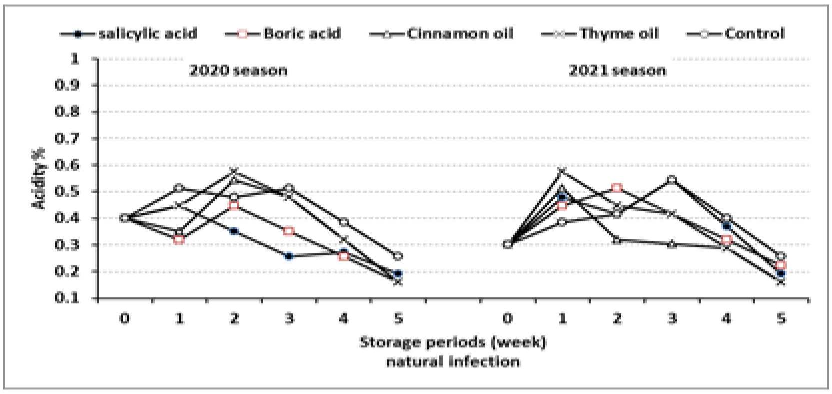


Fig. (9). Effect of post-harvest treatments on TSS% of naturally and artificially mango fruits infected with *Colletotrichum gloeosporioides* during 2020 and 2021 seasons.

Titratable acidity percentage (TA %)

Titratable acidity (TA) of mango fruits was significantly decreased in all treatments with the progress of cold storage period in both seasons of the study (Fig10). In natural infection, fruits treated by Cinnamon and Thyme oils have recorded the lowest TA percentage and its untreated fruit have recorded the highest TA percentage in the both seasons. While in artificial infection, no significant differences between fruit treatments but its untreated fruit gave the highest value of TA percentage in the both seasons.



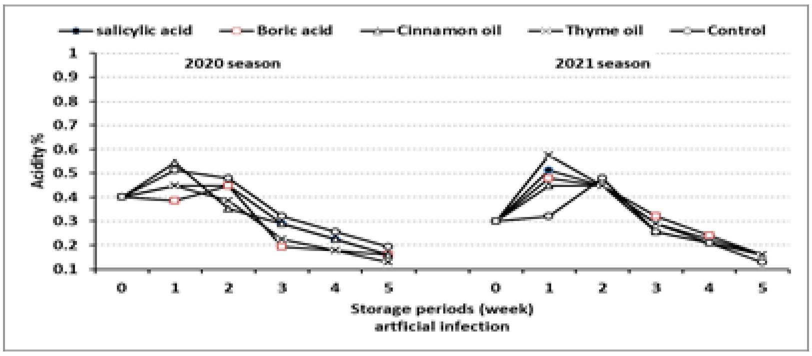
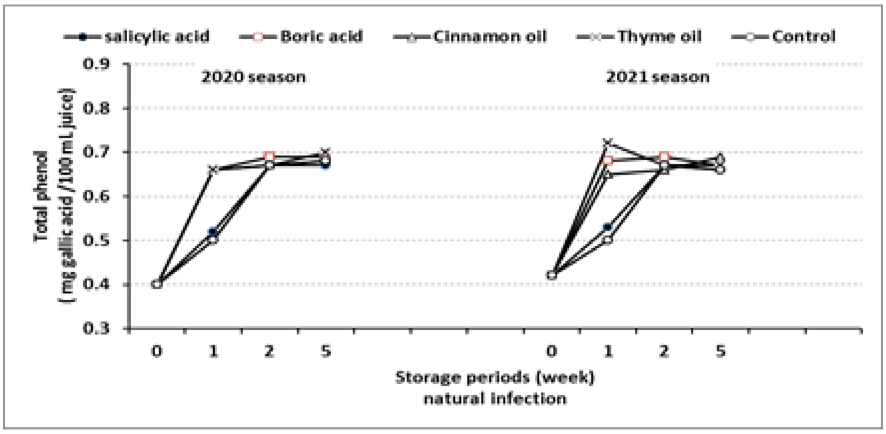


Fig. (10). Effect of some post-harvest treatments on acidity% of naturally and artificially mango fruits infected with *Colletotrichum gloeosporioides* during 2020 and 2021 seasons.

Total phenolic contents (TPC)

Total phenolic contents (TPC) were significantly increased in all treatments during cold storage (Fig. 11). After 5 weeks, in both seasons, the highest total phenolic contents (mg gallic acid /100 mL juice) values were recorded in natural infection by Thyme oil treatment and by Cinnamon oil treatment in artificial infection. While, the lowest TPC was recorded for untreated fruits in the both infection.



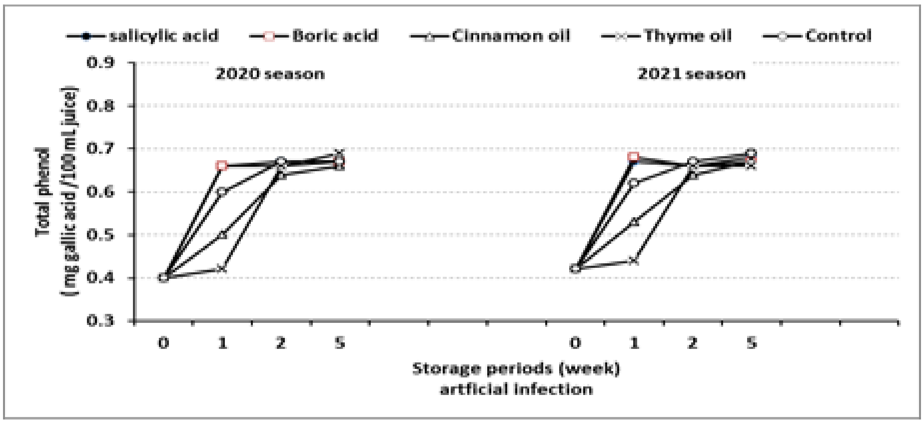


Fig. (11). Effect of some post-harvest treatments on Total phenols (mg gallic acid /100 mL juice) of naturally and artificially mango fruits infected with *Colletotrichum gloeosporioides* during 2020 and 2021 seasons.

Polyphenol oxidase activity (PPO)

Polyphenol oxidase activity (U/min.g FW) of mango fruits was significantly increased until 2 weeks of storage then decreased after that in all treatments in both natural and artificial infections in both seasons (Fig.12).In both natural and artificial infections, fruits treated by Cinnamon and Thyme oils recorded the highest PPO in the two seasons while the untreated fruit recorded the lowest PPO.

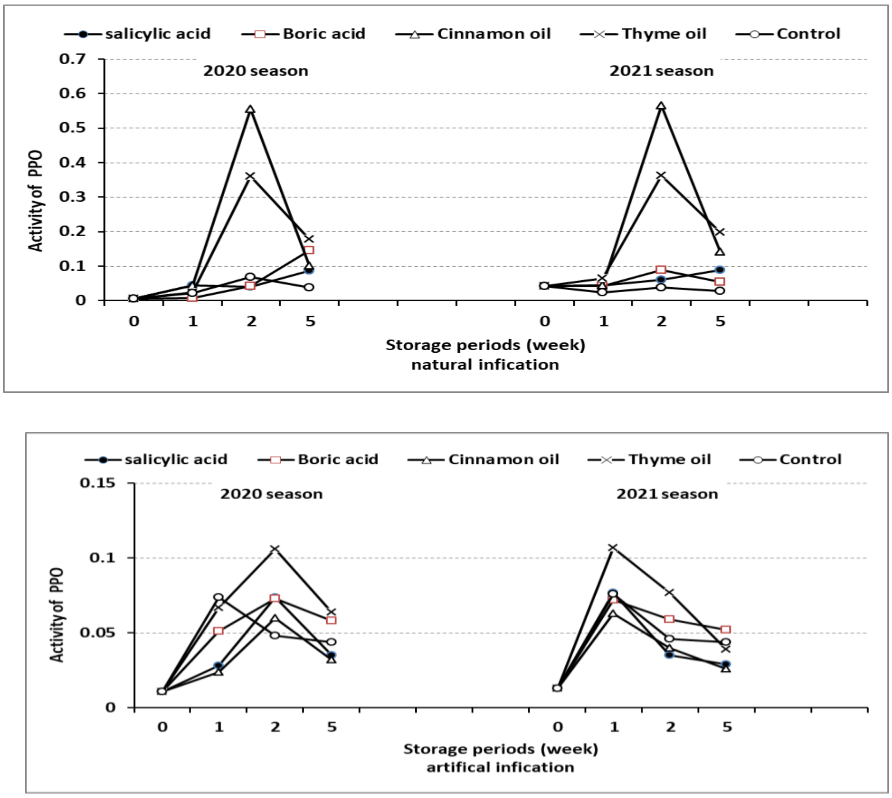


Fig. (12). Effect of some post-harvest treatments on polyphenol oxidase activity (U/min.g FW) of naturally and artificially mango fruits infected with *Colletotrichum gloeosporioides* during 2020 and 2021 seasons.

DISCUSSIONS

The present work aimed to evaluate the capability of certain acids and oils to induce resistance of Kiett Mango fruits against *Colletotrichum gloeosporioides in vitro* and *in vivo*. E In a previous report, **Wu *et al*., (2011)** stated that Thyme oil inhibits growth of different plant pathogens' mycelial including *C. gloeosporioides***.** **Xing Huang *et al*., (2021)** observed in his study by scanning electron microscopy (SEM), that *C. gloeosporioides* hyphae were morphologically modified due to the effect of essential oils and generally spotted compared with untreated mycelial. Additionally, several researchers reported that Cinnamon and clove represent good sources of antifungal compound (**Soliman and Badeaa, 2002; Combrinck *et al*., 2011 and Zeng *et al*., 2012)**. The effects of Salicylic Acid (SA) on postharvest diseases are due to its direct antimicrobial activity and the elicitation of resistant responses, and firmness maintaining. Reasons of raised fruit resistance induced to the pathogen are due to accumulation of large amount of phenolic compounds and promotion of lignin (**Zeng *et al*., 2006),** while Borate treatment may stimulate ROS accumulation in fungal spores leading to inhibition of spores germination **(Xuequn *et al*., 2012**). **Quiróz-López *et al*. (2021)** found that Salicylic acid and Methyl Jasmonate inhibited the germination of *Colletotrichum* sp. spores after 24 hours of incubation *in vitro* and lesion resulted from the fungal mycelial growth on potato dextrose agar (PDA) medium was found to be reduced in diameter when compared with non-treated fruits (control). Furthermore, Thyme oil was found to directly inhibit pathogen growth and spore germination by affecting the enzymes active sites and cellular metabolism **(Arrebola *et al*., 2010).** In our work, Thyme oil showed the highest efficacy in inhibiting fungal growth followed by Cinnamon oil, giving inhibition percentage of 77.8 and 61% for both oil respectively at their concentrations of 10000ppm and both Salicylic and Boric acids caused complete mycelial growth inhibition at their concentration of 500, 3000ppm, respectively. While in artificially inoculated fruits, the treatment by Cinnamon oil and Thyme oil found to significantly reduce anthracnose disease incidence and severity compared to non-treated control for a period of five weeks. In this regard, **Malick *et al*. (2014)** previously reported that the Thyme oil has great potentiality for reducing the anthracnose incidence during the postharvest supply chain. Additionally, they mentioned that further investigation should be carried out for naturally infected fruit in order to provide an effective decay control measure to the organic avocado fruit industry furthermore, **Marc-Chillet, (2020)** found that treatment with thymol limits the necrosis development resulted from the pathogen and attributed that to that thymol treatment can stimulate some polyphenols biosynthesis particularly gallic acid and resorcinol synthesis, involved in fruit resistance to postharvest disease. Finally, A**bd-Alla and Haggag (2013)** reported the antifungal effect of essential oils on anthracnose in mangoes by dipping treatment. It is agreed that, combination of different physical, chemical, and physiological characteristics is responsible for final fruit quality. In this study, the lowest values of weight loss percentage were resulted from Thyme oil treatment in natural infection while in artificial infection, Cinnamon oil caused the lowest ones in two seasons. The weight loss was attributed mainly to water loss from the fruit tissues and partially due to respiration process. These results agree with **Gerefa *et al*. (2015)** in mango fruits. On table grapes, **Ali *et al*. (2010)** found that postharvest treatment with essential oil had significantly reduced weight loss. These findings are in harmony with those mentioned by **Serrano *et al*. (2005)** as they reported that, there was a positive effect of eugenol, thymol and menthol in reduction of weight loss in sweet cherries treated with essential oil.

Concerning fruits firmness, all treatments maintaining firmness compared to control treatment. **Junyu *et al*. (2017)** attributed the effect of SA on firmness to the suppression of conversion of insoluble protopectin into water soluble pectin.

Additionally, the findings of the present study agree with those of **Gerefa *et al.*, (2015)** that found that treatment of mango fruits with Cinnamon and ginger essential oils apparently saved their flesh firmness for a long period at the storage compared with the non-treated (control) and they due the effect to reduction of the polysaccharides such as starch to di and mono saccharine.

Color skin of mangos were evaluated based on the lightness (L*) and hue angle (h^o), Thyme oil fruits treatment gave the highest value of h^o in the two seasons. This result agrees with **Malick *et al*. (2014)** he noted that Thyme oil incorporated chitosan coating enabled fruit firmness maintaining and delaying ripening which was shown by the delayed pulp color (yellow, higher h °) development of avocado fruit tissues ('Hass'). Concerning the TSS, the Thyme oil caused the lowest percentage of TSS in the two seasons compared with the other treatments. This result agrees with **Gerefa *et al.* (2015)** who noted that TSS % increases possibly due to increased respiration rates and fungi infection. TSS % of the fruits treated with essential oils increases slower than the control treatment which increases very rapidly. **Hassan *et al*. (2014)** found that TSS increase in the fruits pulp as the storage period extends could be due to degradation of the complex in soluble compounds like sugars that are the major components of TSS content in the fruits. In addition, decreasing in acidity could be due to leakiness of tonoplast membranes at low temperature; this in turn would allow vacuolar malic acid into the cytoplasm, where it would come in contact with cytoplasmic malic acid decarboxylase **(Klein and Lurie, 1991).**

Plant resistance and defense mechanism towards invasive plant pathogens are mainly attributed and related to the plant species phenol content. Thyme oil (thymol active ingredient) improve antioxidant capacity and scavenging activity leading to enhancement of avocado fruit tissues' substance ('Hass') against *C. gloeosporioides* **(Malick *et al*., 2014).** Our results are accordance with **Supriya *et al*., (2020)** who found that total phenol of three mango cultivars were augmented during fruit developing , maturity and ripening stages additionly it worth to mention that the Thyme oil in combination with modified atmosphere packaging was shown to increase the concentrations of total phenols and flavonoids (catechin), in avocado cultivars (**Sellamuthu *et al*., 2013**).

Finally, the PPO is known to be involved in lignification of host plant cells and considered as key enzyme related to defense reaction against pathogen infections **(Chen *et al*., 2014)**. **Qaoud (2019)** noted that Spraying Naomi Mango with certain plant extract such Turmeric Extract decreased the enzymes activity PPO and Peroxidase (POD) in fruit than control and that delays fruit ripe and that important in fruit marketing **Venkatesan and Tamilmani (2010)** reported that the phenols decreased while ripening, both in the treated and control fruits. While, the activity of peroxidase, polyphenoloxidase and catalase increased in *Mangifera indica* L. var. Neelum. While, the PPO activity of the fruits showed a decrease during post-harvest ripening **(Othman, 2012)**. SA treatment increased the activities of polyphenoloxidase and the content of total phenolic compounds in mango fruit during storage period after inoculation **(Junyu *et al*., 2017**).

CONCLUSION

It could be concluded that treatment with Thyme and Cinnamon oils at 10000ppm as a postharvest treatment can present an effective method to prolong conservation of "Kiett" mango fruit quality and its storability under storage conditions of 13±1°C and 90% relative humidity (RH).

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RESEARCH ARTICLE

Effect of certain postharvest treatments on the anthracnose disease infecting mango fruits

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