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Control of Anthracnose Disease on Sweet Peppers Lirica Rz (F1- Hybrid) using Certain Safe Two Food Additivesor Two Salts

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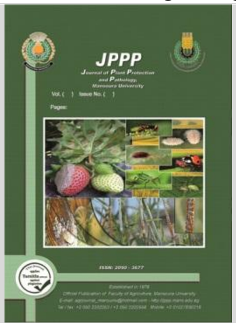

ABSTRACT

This study assessed the effectiveness of potassium sorbate, citric acid, sodium bicarbonate, and calcium chloride as pre- and postharvest treatments to enhance resistance in Lirica RZ (F1 Hybrid) sweet peppers against *Colletotrichum gloeosporioides*. Potassium sorbate was the most effective at inhibiting fungal growth, followed by citric acid, while sodium bicarbonate and calcium chloride were less effective. Sweet peppers treated with potassium sorbate or citric acid showed significantly reduced anthracnose incidence, better quality preservation, lower weight loss, and delayed ripening in both the 2021 and 2022 test seasons. These treatments also improved fruit firmness and maintained higher total soluble solids (TSS) compared to untreated controls.

Keywords: Sweet pepper, food additives, salts, anthrconsee,*Colletotrichum gloeosporioides*.

INTRODUCTION

Sweet pepper (*Capsicum annuum L.*) is a globally significant vegetable crop, prized for its rich nutritional profile, including essential micronutrients, antioxidants, and sufficient levels of vitamins C and A to meet daily human requirements. Additionally, its unique flavor enhances its appeal (Ghasemnezhad et al., 2011). Although research on using food additives or salts to control anthracnose in colored peppers is limited, some studies suggest their effectiveness in reducing postharvest fruit decay.

Anthracnose, caused by various *Colletotrichum* species, is a severe plant disease affecting numerous crops, including cereals, legumes, vegetables, perennial plants, and fruits, resulting in significant global losses (Jeger & Bailey, 1992; Welideniya et al., 2019). In tropical and subtropical regions, the *Capsicum* genus suffers considerable economic losses during postharvest stages due to anthracnose caused by *Colletotrichum* species (Park et al., 2012). This disease, particularly caused by *Colletotrichum capsici*, severely impacts peppers at both pre- and postharvest stages, reducing yields substantially (Ratanacherdchai et al., 2007). Both mature (red, yellow, orange, and green) and immature peppers are susceptible to damage by the anthracnose fungus (Roberts et al., 2018).

Safe food additives and salts, recognized as Generally Recognized as Safe (GRAS) compounds, are permissible for managing postharvest diseases in fruits and vegetables (Palou et al., 2002). Several salts, including ammonium carbonate, ammonium bicarbonate, sodium bicarbonate, sodium benzoate, potassium sorbate, and sodium carbonate, have demonstrated efficacy in controlling postharvest diseases (Smilanick et al., 2008; D'Aquino et al., 2013; Youssef et al., 2014; Montesinos-Herrero et al., 2016). Salts such as sodium bicarbonate, sodium benzoate, sodium metabisulfite, and potassium metabisulfite have been effective against postharvest anthracnose in crops like papaya. For instance, Hasan et al., (2012) observed that sodium bicarbonate at specific concentrations completely inhibited the mycelial growth of *Colletotrichum gloeosporioides* during a week-long incubation period. Similarly, (Sivakumar et al., 2002) reported that ammonium carbonate was more effective than sodium bicarbonate in managing anthracnose in papaya, particularly when combined with wax applications.

(Ajith and Lakshmidevi ,2011) highlighted the potential of sodium and potassium salts in controlling *C. capsici*, recommending their inclusion in integrated postharvest disease management strategies. Furthermore, da Costa Paixão et al., (2020) demonstrated that calcium chloride (7% solution) helped maintain the firmness of green peppers during immersion treatments. Studies by Jitareerat et al., (2018) found that sodium carbonate and potassium sorbate effectively inhibited spore germination in pathogenic fungi such as *C. gloeosporioides*, *C. capsici*, and *Fusarium* species. Somapala et al., (2015) observed that soil applications of potassium salts at double or triple the recommended fertilization levels reduced anthracnose incidence, minimized postharvest losses (30–40% of total yield), and improved plant growth and fruit quality, including firmness and cell wall thickness.

This study evaluates the impact of pre- and postharvest treatments using sodium bicarbonate, citric acid, potassium sorbate, and calcium chloride to mitigate anthracnose in peppers during storage. Pathological parameters, including disease incidence and severity under cold storage, were assessed alongside fruit quality attributes such as firmness, total soluble solids (TSS), and weight loss.

MATEERIALS AND METHODS

Isolation and Identification

Colored sweet pepper fruits from the Behaira Governorate in Egypt that showed symptoms related to

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anthracnose were used to isolate the fungus *Colletotrichum gloeosporioides*. After cutting them into small fragments, the infected fruits were surface sterilized for two minutes using a solution of 1% sodium hypochlorite and then washed three times with sterile distilled water.

After being cultivated on Potato Dextrose Agar (PDA) media, the tissues were incubated at 25°C. The isolates' pathogenicity was verified by applying Koch's postulates. Conidia from 10-day-old pure cultures were utilized for inoculations, and sub-culturing was done every ten days.

Molecular Identification

By using the internal transcribed spacer (ITS) region of rDNA, which is renowned for its precision and dependability, the fungal isolate was molecularly identified. An approximately 500-bp DNA fragment was obtained via ITS sequencing, purified, and sequenced. BLASTn sequence comparisons showed 99.48% similarity to the sequence of isolate PT0314 of Colletotrichum sp. With accession number OP847399, the sequence was added to the GenBank database.

Plant Materials

The sweet pepper cultivar Lirica RZ (F1-Hybrid) was cultivated in a multispan greenhouse with sandy soil in the Behaira Governorate. Fresh, seemingly healthy fruits were gathered from the plants. To guarantee experimental consistency, the fruits were chosen based on their equivalent development phases, homogeneity, and lack of obvious damage.

Tested Chemical Treatments

Al Gomhoria Company for Drugs and Chemicals supplied the food-grade sodium bicarbonate ($NaHCO_3$, code E-500), calcium chloride ($CaCl_2$, code E-509), potassium sorbate ($C_6H_7O_2K$, code E-202), and citric acid ($C_6H_8O_7$, code E-330) that were tested.

Preparation of Food Additives and Salt Solutions

The tested salts and additions were dissolved in tap water at a concentration of 3 g/L to create spray solutions. Prior to application, the solutions were well combined.

Experiment 1:

Preharvest Application of Food Additives and Salts

In a multispan greenhouse in the Behaira Governorate, yellow sweet pepper plants grown in a protected farming system were the subject of this experiment in the growing seasons of 2021 and 2022. Eight rows (0.8 × 70 m) made up the experimental design, which was then subdivided into ten 7 m plots. To avoid spray interference, the plots were separated by a 2-meter isolation strip. A completely randomized block design (CRBD) was used in the experiment.

Solutions of calcium chloride, potassium sorbate, citric acid, or sodium bicarbonate at a concentration of 3 g/L were sprayed on pepper plants three times. Two weeks apart, sprays were administered during the bloom stage, with the last one taking place two days prior to harvest. Control plants were drenched with water, while treated plants were sprayed till runoff. Fruits that had been harvested were taken to the Plant Pathology Research Institute's (ARC) Postharvest Diseases Research Department for additional examination.

Experiment 2: Postharvest Treatments of Sweet Pepper

The mature, at least 50% colored yellow sweet pepper fruits (cv. Lirica RZ (F1-Hybrid)) were bought from commercial orchards in the Giza Governorate. Fruits that were uniformly healthy and free of blemishes and damage were chosen. The fruits were split into two groups: one for trials of artificial inoculation and the other for the research of natural infection.

Fruits were surface sterilized with 70% ethanol for two minutes, rinsed with sterile distilled water, and allowed to air dry in an aseptic environment in preparation for artificial inoculation. A stainless-steel rod with a diameter of 2 mm was used to puncture each fruit in the center of one side. A conidial suspension of C. gloeosporioides (105 conidia/mL) was used to inoculate the fruits, and they were then kept for 24 hours at 7°C and 90% relative humidity (RH).

Fruits were then air-dried under aseptic circumstances after being rinsed for two minutes in solutions containing the tested compounds (3 g/L). For four weeks, all fruits were kept at 7 ± 1°C with 90% relative humidity in carton boxes that were arranged in a single layer, with three boxes per treatment (9 fruits/box).

Assessment of Anthracnose Disease

(A) Disease Incidence (%): The percentage of fruits affected by anthracnose was calculated using the formula: \text{Disease Incidence (%) = } \left(\frac{\text{Number of decayed fruits}}{\text{Total number of stored fruits}} \right) \times 100

(B) Disease Severity (%): Calculated as: \text{Disease Severity (%) = } \left(\frac{\Sigma \text{decayed area (%) of each fruit}}{\text{Number of fruits per replicate}} \right) \times 100

The scoring system was as follows:

- 0: No infection
- 1: Low infection (≤25%)
- 2: Moderate infection (25–50%)
- 3: Severe infection (50–70%)
- 4: Very severe infection (≥70%)

Fruit Quality Parameters

- **Fruit Weight Loss (FWL %):** Determined using the equation: \text{FWL (%) = } \left(\frac{\text{Wi – Ws}}{\text{Wi}} \right) \times 100Where Wi = initial fruit weight, Ws = sampling weight.
- **Total Soluble Solids (TSS):** Measured using an Atago hand refractometer (Japan) on juice extracted from three fruits. Results were expressed as TSS (%).
- Firmness: Measured using an Ametec Firmness Tester with an 8-mm probe on both equatorial sides after removing the fruit skin. Results were expressed in kg/cm².

Statistical Analysis

Statistical analysis was performed using CoStat version 6.311 (CoHort Software).

RESULTS AND DISCUSSION

Results

Isolation: Using the single spore technique, ten isolates of *Colletotrichium gloeosporioides* were recovered from infected sweet potatoes in Behair. Their pathogenic potential was then assessed.

The most harmful one was chosen, and its DNA was sequenced. The sequence was identified as *Colletotrechum gloeosporioides* in the GenBank database with accession number OP847399.

Effectiveness of certain food adddditives and salts to suppress *C. gloeospoides In vitro* :

The impact of calcium chloride, citric acid, potassium sorbate, and sodium bicarbonate on *Colletotrichum* *gloeosporioides's* linear growth. At all studied concentrations, the growth of *Colletotrichum gloeosporioides* was totally suppressed by potassium sorbate.

Other *Colletotrichum gloeosporioides* mycelial development was greatly reduced by applied treatments with concentrations more than 1 g/L (Fig.1).

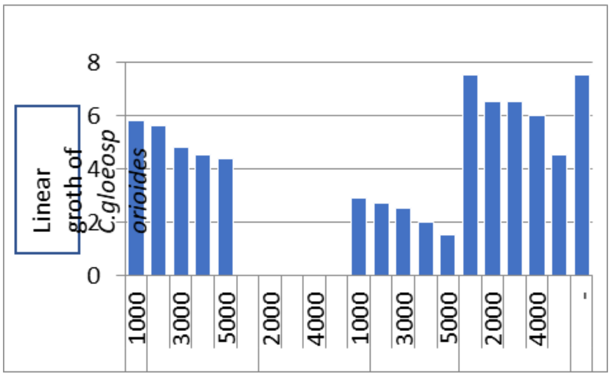

Fig. 1. Effectof sodium bicarbonate, potassium sorbate, citric acid and calcium chloride on linear growth of *Colletotrichum gloeosporioides*.

Fig.2. Anthracnose symptoms on lirica pepper fruit.

Disease incidence of pre-harvest treatments with food additive or salts on anthracnose disease of Lirica RZ (F1-Hybrid) cv.(pepper):

Anthracnose disease in Lirica peppers was considerably reduced in 2021 thanks to pre-harvest treatments of pepper plants with two food additives and two salts. Naturally infected fruits kept at 7°C for 28 days showed a significant impact on disease incidence and severity (Table.1). The benefits of two food additives or two salts in preventing anthracnose disease in naturally infected peppers were amplified by a 28-day storage period at 7°C.

Fruits naturally infected with anthracnose disease were treated with potassium sorbate, citric acid, and calcium chloride, as opposed to the control that was kept at 7°C for 28 days. Pepper fruits responded significantly well to pre-harvest treatments with sodium bicarbonate. In terms of disease incidence, the artificial pepper inoculation produced (Tables.1) 100% disease incidence in the fruits' control treatment during the 28 days of cold storage in the 2021 season.

Anthracnose disease in Lirica peppers was considerably reduced during the 2022 growing season when pepper plants were treated with two food additives and two salts prior to harvest. Naturally contaminated fruits that were kept at 7°C for 28 days had a significantly higher disease incidence (Table 2). The beneficial effects of two food additives or two salts in preventing anthracnose disease in naturally infected peppers were demonstrated by extending the storage duration to 28 days at 7 °C and 90% relative humidity. For 21 days of cold storage, anthracnose disease was completely controlled when treated with potassium sorbate, calcium chloride, or citric acid. For 14 days of cold storage, potassium sorbate also provided a combination inhibition of anthracnose disease.

Table 1. Anthracnose incidence (%) on Lirica sweet Pepper pre-harvest-sprayed with food additives and salts during seasons 2021 in Behaira Governorates, then stored at 7ºC and 90% RH for up to 28 days.

Treatment	Disease Incidence (%) Season 2021							
	Natural infection Storage period per weeks				Artifical infection Storage period per weeks			
	1	2	3	4	1	2	3	4
Sodium Bicarbonate	0.0	0.0	22.2	33.3	0.0	11.1	33.3	44.4
Potassium sorbate	0.0	0.0	0.0	11.1	0.0	0.0	11.1	22.2
Citric acid	0.0	0.0	0.0	22.2	0.0	11.1	22.2	33.3
Calcium chloride	00	0.0	0.0	11.1	0.0	22.2	33.3	44.4
Control	11.1	22.2	33.3	44.4	11.1	33.3	55.6	100
LSD .0.5%	2.1	2.9	2.3	1.9	2.1	1.4	1.9	3.6

Table 2. incidence (%) on Lirica sweet Pepper pre-harvest-sprayed with food additives and salt during growing seasons 2022 in Behaira Governorates, then stored at7ºC and 90% RH for up to 28 days.

Treatment	Disease Incidence (%) Season 2022							
	Natural infection Storage period per weeks				Artifical infection Storage period per weeks			
	1	2	3	4	1	2	3	4
Sodium Bicarbonate	0.0	0.0	33.3	44.4	0.0	22.2	22.2	44.4
Potassium sorbate	0.0	0.0	0.0	11.1	0.0	0.0	0.0	22.2
Citric acid	0.0	0.0	0.0	33.3	0.0	22.2	22.2	33.3
Calcium chloride	00	0.0	0.0	22.2	0.0	33.3	33.3	44.4
Control	0.0	11.1	44.4	55.5	0.0	44.4	55.6	100
LSD .0.5%	-	2.1	1.6	2.2	-	1.8	2.1	3.6

The percentage of anthracnose illness severity of pepper (Lirica) potassium sorbate was greatly decreased by all tested food additives and salts, according to data in Tables 3 and 4.

Table 3. Anthracnose severity (%) on Lirica Pepper preharvest-sprayed with salts and acid during growing seasons 2021 in Behaira Governorate, then stored at 7ºC and 90% RH for up to 28 days.

Treatment	Disease Severity (%) 2021							
	Natural infection Storage period per weeks				Artifical infection Storage period per weeks			
	1	2	3	4	1	2	3	4
Sodium Bicarbonate	0.0	0.0	4.4	6.7	0.0	2.2	6.7	35.6
Potassium sorbate	0.0	0.0	0.0	2.2	0.0	0.0	2.2	8.9
Citric acid	0.0	0.0	0.0	4.4	0.0	2.2	4.4	20
Calcium chloride	00	0.0	0.0	2.2	0.0	4.4	6.7	35.6
Control	2.2	4.4	6.7	8.9	2.2	6.7	22.2	100
LSD .0.5%	2.5	4.1	3.5	3.2	2.5	3.5	9.5	9.5

Table 4. Anthracnose Severity (%) on Lirica Pepper pre-harvest-sprayed with salts and acid during growing seasons 2022 in Behaira Governorates, then stored at 7ºC and 90% RH for up to 28 days.

Treatment	Disease Severity (%)							
	2022							
	Natural infection				Artifical infection			
	Storage period per weeks				Storage period per weeks			
	1	2	3	4	1	2	3	4
Sodium Bicarbonate	0.0	0.0	4.4	6.7	0.0	2.2	6.7	35.6
Potassium sorbate	0.0	0.0	0.0	2.2	0.0	0.0	2.2	8.9
Citric acid	0.0	0.0	0.0	4.4	0.0	2.2	4.4	20
Calcium chloride	00	0.0	0.0	2.2	0.0	4.4	6.7	35.6
Control	0.0	4.4	6.7	8.9	0.0	6.7	22.2	100
LSD .0.5%	-	4.1	3.5	3.2	-	3.1	3.5	3.9

The lowest percentages were 2.2% and 8.9, respectively, in natural and artificial infection.Control, however, recorded the highest value.During 28 days of cold storage, the rates of spontaneous and artificial infection were 8.9% and 100%, respectively.

Efficacy of postharvest applications with food additives and salts on Anthracnose incidence (%) onLirica sweet Pepper :

The frequency of anthracnose disease in naturally infected fruits after 14 days of cold storage was considerably reduced as a result of postharvest treatments of food additives and salts during season 2021/22 (Tables 5,6).

Table 5. Effect of postharvest with sodium bicarbonate, potassium sorbate , citric acid and calcium chloride on Disease Incidence percentage Lirica Pepper natural infectionand artificial infection during growing seasons 2021, then stored at 7ºC and 90% RH for up to 28 days.

Treatment	Disease Incidence (%)							
	Season 2021							
	Natural infection				Artifical infection			
	Storage period per weeks				Storage period per weeks			
	1	2	3	4	1	2	3	4
Sodium Bicarbonate	0.0	0.0	0.0	11.1	0.0	0.0	0.0	11.1
Potassium sorbate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Citric acid	0.0	0.0	0.0	11.1	0.0	0.0	0.0	11.1
Calcium chloride	0.0	11.1	22.2	33.3	0.0	11.1	22.2	33.3
Control	0.0	22.2	33.3	44.4	0.0	33.3	44.4	100
LSD .0.5%	-	0.8	0.5	0.9	-	0.5	0.8	0.8

Table 6. Effect of postharvest with sodium bicarbonate, potassium sorbate , citric acid and calcium chloride on Disease Incidence percentage Lirica Pepper natural infection and artificial infection during growing seasons 2022, then stored at 7ºC and 90% RH for up to 28 days.

Treatment	Disease Incidence (%)							
	Season 2022							
	Natural infection				Artifical infection			
	Storage period per weeks				Storage period per weeks			
	1	2	3	4	1	2	3	4
Sodium Bicarbonate	0.0	0.0	0.0	11.1	0.0	0.0	0.0	22.2
Potassium sorbate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Citric acid	0.0	0.0	0.0	11.1	0.0	0.0	0.0	22.2
Calcium chloride	0.0	11.1	22.2	33.3	0.0	22.2	33.3	44.4
Control	0.0	22.2	33.3	44.4	0.0	44.4	55.5	100
LSD .0.5%	-	0.8	0.5	0.9	-	0.8	0.5	0.9

The beneficial effects of food additives and salts in reducing the prevalence of anthracnose disease in naturally infected Lirica sweet peppers were amplified by a longer storage duration of 28 days at 7°C. However, during 28 days of cold storage, potassium sorbate completely prevented anthracnose in naturally infected Lirica sweet peppers. Lirica sweet pepper fruits respond well to the following important postharvest treatments: calcium chloride, citric acid, and sodium bicarbonate. When Lirica sweet pepper fruits were artificially inoculated, the control treatment saw a 100% disease incidence. On postharvest treated Lirica sweet pepper fruits, potassium sorbate totally prevented the occurrence of anthracnose disease. But when compared to the control, sodium bicarbonate, citric acid, and calcium chloride also markedly decreased the incidence of anthracnose illness in artificially infected Lirica sweet peppers.

Efficacy of postharvest applications with food additives and salts on Anthracnose severiety(%) onLirica sweet Pepper :

The severity of anthracnose disease was considerably reduced in both naturally and artificially infected fruits during 28 days of cold storage as a result of postharvest treatments with food additives and salts throughout seasons 2021/22 (Tables 7,8).During 28 days of cold storage over two seasons, potassium sorbate demonstrated combility inhibition of disease severity in both natural and artificial infection postharvest treated Lirica sweet pepper crops. Disease severity in the control treatment during Season 2021 was 22.2% for natural and 60% for artificial infection of Lirica sweet pepper fruits.In contrast, season 2022 saw 15.6% and 53.3%, respectively.

Table 7. Effect of postharvest with sodium bicarbonate, potassium sorbate, citric acid and calcium chloride on Disease Severiety percentage Lirica Pepper natural infection and artificial infection during growing seasons 2021, then stored at 7ºC and 90% RH for up to 28 days.

Treatment	Disease Severiety (%)							
	Season 2021							
	Natural infection				Artifical infection			
	Storage period per weeks				Storage period per weeks			
	1	2	3	4	1	2	3	4
Sodium Bicarbonate	0.0	0.0	0.0	2.2	0.0	0.0	0.0	2.2
Potassium sorbate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Citric acid	0.0	0.0	0.0	2.2	0.0	0.0	0.0	2.2
Calcium chloride	0.0	2.2	4.4	6.7	0.0	2.3	4.4	6.7
Control	0.0	4.4	8.9	22.2	0.0	6.7	13.3	60
LSD .0.5%	-	1.7	1.2	2.1	-	3.8	2.7	6.2

Table 8. Effect of postharvest with sodium bicarbonate, potassium sorbate , citric acid and calcium chloride on Disease Severity percentage Lirica Pepper natural and artificial infection during growing season 2022, then stored at 7ºC and 90% RH for up to 28 days.

Treatment	Disease Severiety (%)							
	Season 2022							
	Natural infection				Artifical infection			
	Storage period per weeks				Storage period per weeks			
	1	2	3	4	1	2	3	4
Sodium Bicarbonate	0.0	0.0	0.0	4.4	0.0	0.0	0.0	4.4
Potassium sorbate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Citric acid	0.0	0.0	0.0	2.2	0.0	0.0	0.0	4.4
Calcium chloride	0.0	2.2	4.4	6.7	0.0	4.4	6.7	8.9
Control	0.0	6.7	8.9	15.6	0.0	8.9	22.2	53.3
LSD .0.5%		1.7	1.2	1.7	-	2.7	6.3	6.2

Effect of Sodium bicarbonate,potassiumsorbate,citric acid and calcium chloride treatments as pre-harvest treatment on physical properties of color pepperfruits during storage periods.

Fruit weight loss percentage

The findings in Figures 3 and 4 illustrate how pre-harvest handling of Lirica pepper fruits affects the percentage of weight loss throughout the 2021–2022 cold storage season.As the storage period came to a close, the proportion of fruit weight loss climbed progressively. During both study seasons, the percentage of weight loss was dramatically reduced by all pre-harvest treatments as compared to untreated Lirica pepper fruits. Lirica fruit plants treated with potassium sorbate and citric acid showed the least amount of weight loss during 28 days of cold storage. On the other hand, during the 2021–2022 seasons, the untreated fruit had the largest weight loss %.Regarding the impact of various pre-harvest procedures. Figures 6 and 9 show the proportion of weight loss in Lirica pepper fruits that were intentionally infected with *Colletotrichum gloeosporioides*. The same results in natural infection mentions above

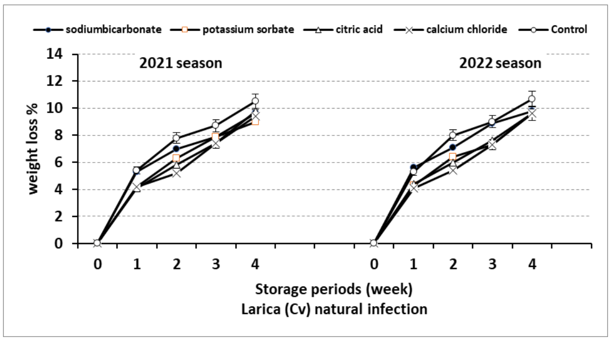

Fig.3. Effect of sprayed preharvest with sodium bicarbonate, potassium sorbate ,citric acid and calcium chloride on weight loss percentage Lirica Pepper during growing seasons 2021/22 in Behaira governorates, then stored at $7^{o}C$ and 90% RH for up to 28 days

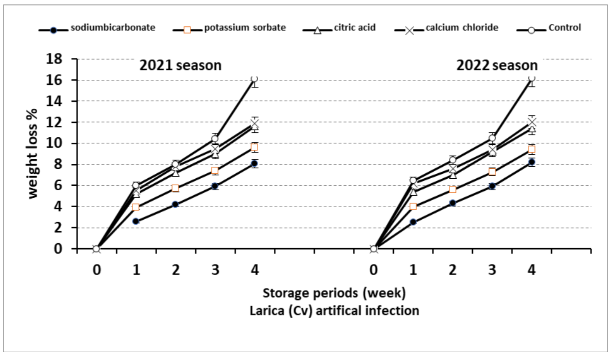

Fig.4. Effect of sprayed preharvest with sodium bicarbonate, potassium sorbate ,citric acid and calcium chloride on weight loss percentage Lirica Pepper during growing seasons 2021/22 in Behaira governorates, then stored at $7^{o}C$ and 90% RH for up to 28 days

Effect of Sodium bicarbonate,potassium sorbate,citric acid and calcium chloride treatments as post-harvest treatment on physical properties of color pepperfruits during storage periods.

Fruit weight loss percentage.

According to the results, the weight loss percentage during the 2021–2022 seasons is affected by the post-harvest treatment of Lirica pepper fruits in Figs. 5 and 6.As the storage period came to a close, the proportion of fruit weight loss climbed progressively. During both study seasons, the percentage of weight loss was dramatically reduced by all post-harvest treatments as compared to untreated Lirica pepper fruits. Lirica fruit plants treated with potassium sorbate and citric acid showed the least amount of weight loss during 28 days of cold storage. On the other hand, during the 2021–2022 seasons, the untreated fruit had the largest weight loss %.Regarding the impact of various post-harvest procedures. Figure 6 shows the proportion of weight loss in Lirica pepper fruits that were intentionally infected with *Colletotrichum gloeosporioides*. The same results in natural infection mentions above

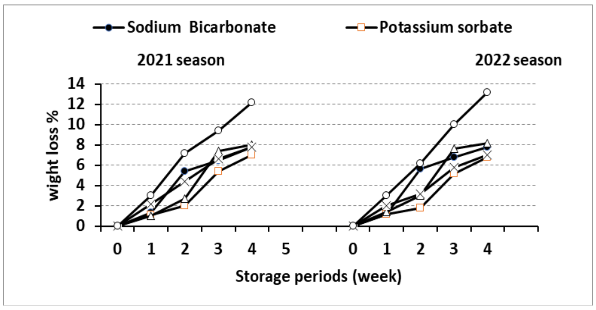

Fig. 5. Effect of postharvest with sodium bicarbonate, potassium sorbate ,citric acid and calcium chloride on weight loss percentage Lirica Pepper natural infection during growing seasons 2021/2022, then stored at 7oC and 90% RH for up to 28 days

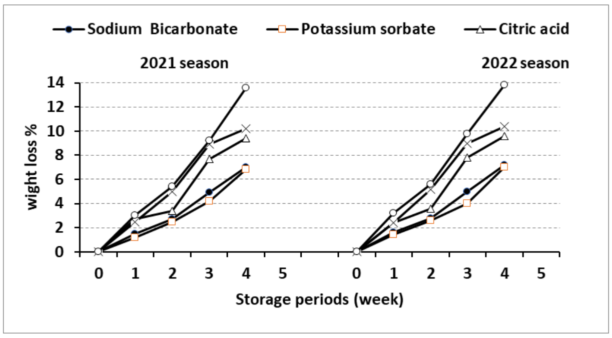

Fig. 6. Effect of postharvest with sodium bicarbonate, potassium sorbate ,citric acid and calcium chloride on weight loss percentage Lirica Pepper artificial infection with *Colletotrichum gloeosporioides*, during growing seasons 2021/2022, then stored at $7^{o}C$ and 90% RH for up to 28 days

Effect of food additive and salts treatments as pre - harvest treatment on Fruit firmness (Kg/cm2)of pepperfruits during storage periods.

Fruit firmness of both natural and artificial infection with *Colletotrichum gloeosporioides* pepper fruits from pre-harvest sprayed plants in Behaira Governorate with various food additives and salts decreased with cold storage compared to harvest time. Potassium sorbate was the most effective treatment to maintain the highest firmness during cold storage in both seasons, 2021/2022 (Figs. 7&8). After being stored for up to 28 days, the control lirica pepper's hardness significantly decreased.

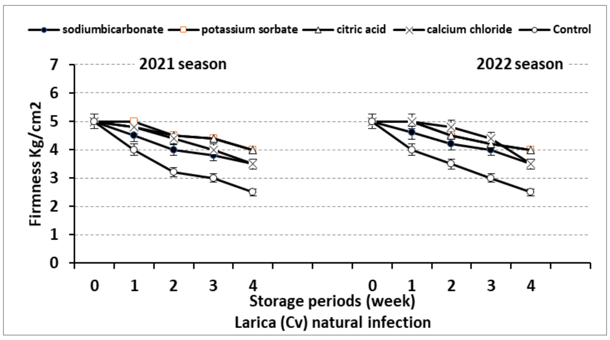

Fig. 7. Effect of pre-harvest treatments on firmness percentage Lirica Pepper during growing seasons 2021/22 in Behaira Governorates, then stored at $7^{o}C$, 90% RH natural infection for up to 28 days

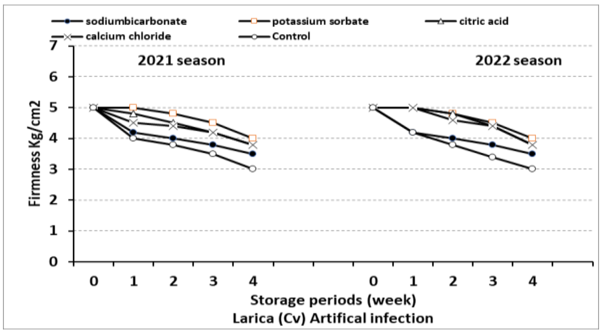

Fig. 8. Effect of sprayed preharvest with sodium bicarbonate, potassium sorbate ,citric acid and calcium chloride on firmness percentage Lirica Pepper during growing seasons 2021/22 in Behaira governorates, then stored at 7ºC and 90% RH for up to 28 days.

Effect of food additive and salts treatments as post - harvest treatment on fruit firmness (Kg/cm2)of pepperfruits during cold storage periods.

The data shown in Figures 9 and 10 showed that, as the storage duration was extended over the course of the two seasons, the fruit firmness of both natural and artificial infections with *Colletotrichum gloeosporioides* gradually and considerably declined, with all treatments retaining firmness in comparison to the control treatment. In contrast to untreated fruits (control) that showed the lowest values during the first and second seasons for both natural and artificial infections, fruits treated with potassium sorbate at the end of the storage period had the maximum fruit firmness during the first and second seasons.

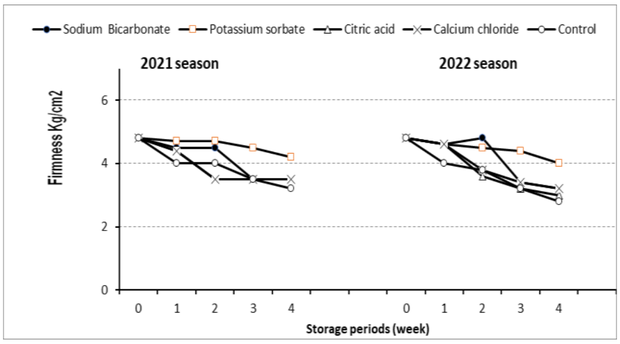

Fig.9. Effect of postharvest with sodium bicarbonate, potassium sorbate ,citric acid and calcium chloride on firmineses percentage Lirica Pepper natural infection during growing seasons 2021/2022, then stored at 7ºC and 90% RH for up to 28 days.

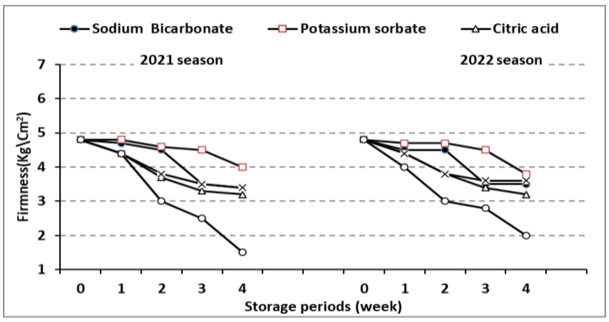

Fig.10. Effect of postharvest with sodium bicarbonate, potassium sorbate ,citric acid and calcium chloride on firmineses percentage Lirica Pepper artificial infection with *Colletotrichum gloeosporioides* during growing seasons 2021/2022, then stored at 7ºC and 90% RH for up to 28 days.

Effect of food additive and salts treatments as pre - harvest treatment on Fruit Total soluble solids percentage (TSS %) percentage of yellow color pepper fruits during storage periods.

The information displayed in Figures 11 and 12 shows that as cold storage times extended throughout the course of the two seasons, the total soluble solid contents of yellow pepper fruits, Lirica, grew progressively and dramatically. Additionally, the data showed that, when compared to the other treatments, the total soluble solid contents of fruits treated with potassium sorbate had the lowest values during the two seasons. On contrast, untreated fruits of both naturally or artificially infection showed the highest percentage of TSS contents in the

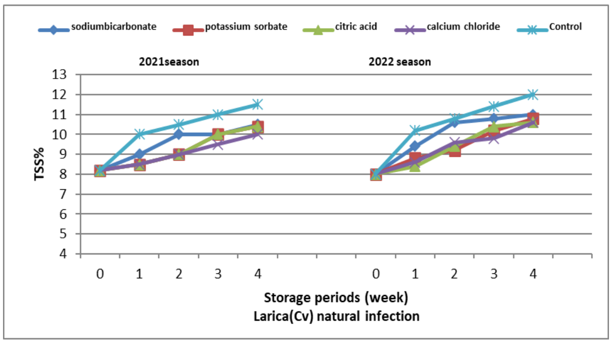

Fig. 11. Effect of pre-harvest treatments on TSS percentage Lirica Pepper during growing seasons 2021/22 in Behaira Governorates, then stored at 7ºC, 90% RH natural infection for up to 28 days.

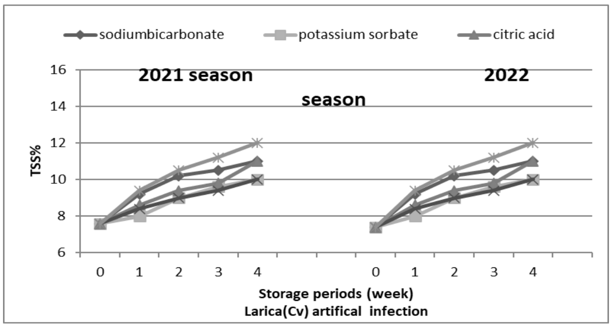

Fig. 12. Effect of pre-harvest treatments on TSS percentage Lirica Pepper during growing seasons 2021/22in Behaira Governorates, then stored at 7ºC ,90% RH artificial infection for up to 28 days.

Effect of food additive and salts treatments as post - harvest treatment on Fruit Total soluble solids percentage (TSS %) percentage of yellow color pepperfruits during storage periods.

The data was displayed in Figure 13. In general, as cold storage times extended over the course of the two seasons, the total soluble solid contents of Lirica sweet pepper fruits grew progressively and dramatically. The postharvest TSS levels of naturally and artificially infected yellow sweet peppers treated with food additives and salts did not differ significantly during the 2021 growing season. During season 2022, potassium sorbate recorded the lowest value of 7.2, while TSS in control recorded the highest value of 9.2%.

Data in Fig.14. TSS values of both naturally and artificially inoculated yellow sweet pepper postharvest treated with food addidtive and salts did not show any significant differences.

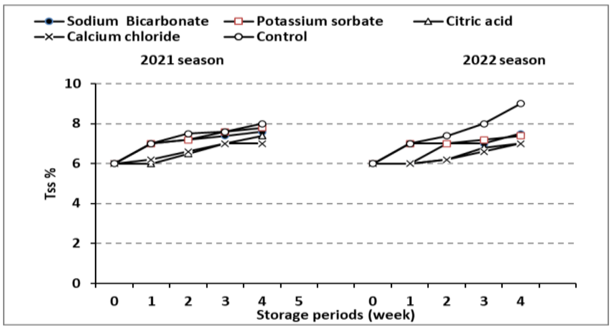

Fig. 13. Effect of postharvest with sodium bicarbonate, potassium sorbate ,citric acid and calcium chloride on TSS percentage Lirica Pepper natural infection during growing seasons 2021/2022, then stored at 7ºC and 90% RH for up to 28 days.

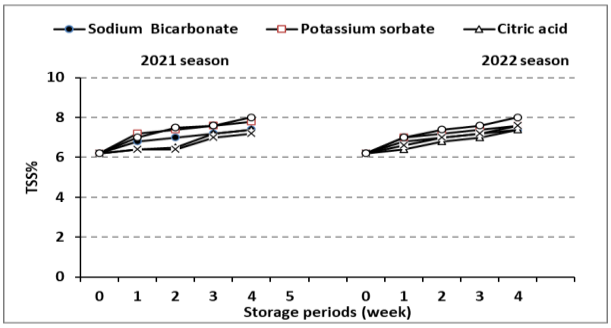

Fig. 14. Effect of postharvest with sodium bicarbonate, potassium sorbate ,citric acid and calcium chloride on TSS percentage Lirica Pepper artificial infection with *Colletotrichum gloeosporioides* during growing seasons 2021/2022, then stored at 7ºC and 90% RH for up to 28 days.

Discussion

This study was carried out to use various morphological and molecular examination methods to identify fungi isolated from plant part (fruits) from E. fungal specie was isolated and identified at the species level using rDNA ITS sequences comparison and analysis.as shown in Fig. 15.

Alternative methods for managing anthracnose disease in pepper fruit have been investigated over two years. The current study explored the potential of food additives and salts as control measures through both laboratory (in vitro) and real-world (in vivo) experiments. Various food additives and salts were tested at different concentrations to evaluate their efficacy in suppressing the mycelial growth of *Colletotrichum gloeosporioides*, a major pathogen isolated from sweet pepper fruit in this study. Notably, potassium sorbate at concentrations of 1–5% completely inhibited the linear growth of this pathogen. Previous research suggested that the antifungal effects of potassium sorbate and sodium carbonate might result from reduced fungal cell turgor pressure, leading to the collapse and shrinkage of hyphae and spores, thereby preventing sporulation (Fallik *et al.*, 1997).

Fadda et al., (2015) demonstrated that potassium sorbate at 2000 mg/L exhibited fungistatic activity against Penicillium expansum, effectively reducing blue mold in apples. Similarly, Palou et al., (2002) found that a 3% sodium carbonate solution reduced the growth of P. digitatum and P. italicum, which cause green and blue mold in mandarins. The present study revealed that a 2% sodium carbonate solution entirely inhibited the spore germination of *C. gloeosporioides*, while a 3% solution completely inhibited spore germination in *C. capsici* and *Fusarium* species. Additionally, when salt solutions were applied to wounded Capsicum fruits before inoculation with *C. capsici*, lesion sizes were reduced by 39–82% compared to untreated controls (Ajith and Lakshmidevi, 2011). Sodium metabisulphite, known for its antimicrobial properties, is commonly used as a food additive (Lindsay, 1985; Russell and Gould, 1991). Studies have shown the inhibitory effects of sulfites on yeasts, molds, and bacteria (Yamane, 2014; Madania et al., 2016).

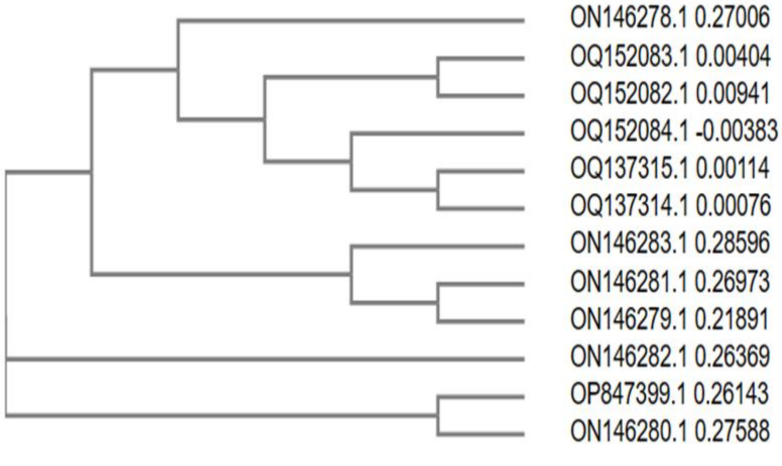

Fig. 15. Unrooted neighbor-joining tree of 12 sequences of Col products of rDNA from *Colletotrichum* species. The branch lengths are proportional to genetic distance

Further investigations revealed that potassium sorbate effectively controlled brown rot at a concentration of 3000 ppm (Madania et al., 2016), and Palou et al., (2009) used it at 200 mM to manage brown rot in stone fruits. Smilanick et al., (2008) observed that combining 0.5% potassium sorbate with a heat treatment (45°C for 5 minutes) completely inhibited the spore germination of *Fusarium* sp., Lasiodiplodia theobromae, and *Colletotrichum musae*. Türkkan et al., (2017) highlighted that carbonate salts are safe, broad-spectrum antimicrobials that do not require extensive regulatory validation.

In the current study, all treatments significantly reduced anthracnose disease incidence and severity in naturally infected fruits during pre- or post-harvest periods, as well as in artificially inoculated fruits stored at 7°C for 28 days. Potassium sorbate exhibited the highest efficacy. Pre-harvest and post-harvest treatments with potassium sorbate and citric acid significantly reduced anthracnose incidence and severity compared to untreated controls over four weeks. Jabnoun-Khiareddine et al., (2016) reported that potassium sorbate reduced fruit rots caused by *Botrytis, Rhizoctonia, Alternaria, and anthracnose.*

In terms of fruit quality, the study found minimal weight loss in healthy fruits treated with potassium sorbate and stored at 7°C for 28 days. Artificially infected fruits treated with 3 g/L calcium chloride showed the highest disease control, but differences in salt concentrations were insignificant. These findings align with Ghafir et al., (2009), who noted a linear relationship between fruit weight loss and storage duration due to moisture loss and respiration.

At the end of the storage period, potassium sorbate-treated fruits retained the highest firmness across two seasons, outperforming untreated controls, which showed the lowest firmness levels. Additionally, total soluble solids (TSS) content increased during cold storage, with no significant differences observed among treatments. Hafez et al., (2010) found that pre-harvest treatments with calcium nitrate, citric acid, and ascorbic acid, whether applied individually or in combination, reduced decay in Le Conte pear fruits, decreased weight loss, and enhanced TSS and sugar content during the marketing period.

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السيطرة على مرض الأنثراكنوز في الفلفل الحلو(Lirica RZ (F1- Hybrid باستخدام نوعين من الأملاح الآمنة

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الملخص

قامت هذه الدراسة بتقييم فعالية سوربات البوتاسيوم وحمض الستريك وبيكربونات الصوديوم وكلوريد الكالسيوم كمعالجات قبل وبعد الحصاد لتعزيز مقاومة الفلفل الحلو Lirica RZ (F1 Hybrid) ضد *Colletotrichum gloeosporioides*. كان سوربات البوتاسيوم هو الأكثر فعالية في تثبيط نمو الفطريات، يليه حمض الستريك، بينما كان بيكربونات الصوديوم وكلوريد الكالسيوم أقل فعالية. أظهر الفلفل الحلو المعالج بسوربات البوتاسيوم أو حمض الستريك انخفاضًا كبيرًا في حدوث مرض الأنثراكنوز، و أفضل حفظًا لجودة الثمار ، وفقدانًا أقل للوزن، وتأخيرًا في النضج في كل من موسمي الاختبار 2021 و2022. كما حسنت هذه المعالجات من صلابة الثماروحافظت على إجمالي المواد الصلبة الذائبة (TSS) أعلى مقارنة بالكنترول .