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Reducing Pre and Postharvest Diseases of Some Economic Fruits by Using Agro-Textiles Treated with Eco- Friendly Materials

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ABSTRACT
Crop protection are the main difficulties that farmers encounter in the agricultural sector. Sunscreen, bird nets, mulch mats, hail protection nets, harvesting nets, and windshields are examples of agrotextiles. The primary reasons for fruit and vegetable crop losses are diseases that develop both before and after harvest. In order to reduce pre- and post-harvest diseases, the purpose of this work was to assess certain environmentally friendly products. Three organic acids i.e. salicylic, sorbic, and benzoic acids were examined in vitro against the inhibitory zone of *Penicillium digitatum*, *Botrytis cinerea*, and *Colletotrichum gloeosporioides* growth at three concentrations: 0.0, 2.5, and 5.0%. According to our results the inhibition zones for *Penicillium digitatum*, *Botrytis cinerea*, and *Colletotrichum gloeosporioides* were more than 11.0, 10.0, and 9.0 mm for salicylic, sorbic, and benzoic acids at 5.0%, respectively. Four salts potassium bicarbonate, sodium benzoate, sodium bicarbonate and potassium sorbate at three different concentrations 0.0, 2.5, and 5.0% were examined. The results showed that the inhibition zone of all tested fungi was considerably recorded by all tested salts. With sodium bicarbonate at 5.0%, the inhibitory zone increased the most, measuring 11.0, 9.0, and 8.0 mm for *Penicillium digitatum*, *Botrytis cinerea*, and *Colletotrichum gloeosporioides*, respectively. The effects of other salts were mild. In vivo tests were used to examine the effects of salicylic acid, benzoic acid, and sodium bicarbonate at a concentration of 5.0% on orange fruit green mold, apple fruit gray mold, and mango fruit anthracnose. Results indicated that all tested treatments significantly reduced the all tested diseases. At a concentration of 5.0%, salicylic acid and benzoic acid completely suppressed the incidence and severity of every diseases that was examined. Meanwhile, sodium bicarbonate produced a moderate effect.

Keywords: agro-textiles, non woven, postharvest diseases, organic acid, salts, green mold, gray mold, anthracnose, orang, apple, mango

1. Introduction
Textiles began to play a role in protecting agricultural crops from pests, by using a special type of fabric to cover trees and different plants, allowing the passage of air and light necessary for photosynthesis to complete the ripening process, and not allowing pests to pass to the fruits. Thus, the pest does not reach the fruits, so we get ripe fruits free from any injuries and reduce the use of pesticides. Likewise, the pest or insect does not find the host through which it breeds and reproduces,

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so successive generations decrease.

Before or after harvest, a number of citrus fruit illnesses result in large losses. Green and blue molds, which are brought on by *Penicillium digitatum* Sacc. and *Penicillium italicum* Wehmer, respectively, are the most harmful diseases that damage citrus (Zhang *et al*., 2005).

The main citrus postharvest diseases are caused by *Geotrichumcitri-aurantii*, *Penicillium digitatum*, and *P. italicum*, which result in sour rot, blue mold, and green mold, respectively (Cheng *et al*., 2020; Bhatta, 2021; Shawky, Heba *et al*., 2023 and Abd-El-Kareem *et al*., 2022).

In the tropics and warmer subtropics, mango fruits (*Mangifera indicca* L.) are frequently grown. It contains essential vitamins, minerals, and fiber for human health (Sethi *et al*., 2011). Anthracnose, which is caused by *Colletotrichum gloeosporioides* (Penz.) Penz and Sacc, is one of the many fruit diseases that affect the quality of mango fruits before and after harvest (Ploetz, 2003; Sangeetha and Rawal, 2008).

Several fungal infections are responsible for postharvest diseases of apples and pears (Sutton 2014). Wounds from insects and birds, as well as damage done before or during harvest, are important entry routes for diseases like *Botrytis cinerea*, which causes grey mold, and *Penicillium expansum,* which causes blue mold (Snowdon 1990). These pathogens typically cause rapid decay of fruit in the pre- and postharvest stage (Wenneker and Thomma, 2020). Usually, these infections cause fruit to rot quickly both pre and post harvest.

Chemical fungicides are applied regularly these days as a method of controlling postharvest diseases, but even when they work, their toxic nature has a negative impact on the ecosystem. To control postharvest diseases, new, safe, and efficient options must be researched (Abd-El-Kareem and Saied 2015; Abd-El-Kareem *et al.*, 2015, 2022).

Few studies on pre-harvest application have been done to control postharvest decay; most research has focused on salts and organic acids as postharvest treatments via dipping or spraying (Nigro *et al.,* 2006). The active element may disrupt the initial stages of infection by acting as an alternate control mechanism while the harm is being caused. (Ippolito and Nigro, 2000 and Youssef *et al*., 2008 and 2012).

In laboratory conditions, the application of salicylic acid and abscisic acid as resistance inducers to pepper fruits considerably reduced the growth of gray mold (Kamara *et al.,* 2016). Plant stress tolerance is greatly influenced by the phenolic hormone salicylic acid (SA). SA spraying both pre and after harvest has improved pear disease control (Jiankang *et al.,* 2006), SA as a pre-harvest treatment in pepper also markedly raised the activities of peroxidase and polyphenol oxidase (Mahdavian *et al.,* 2007). In comparison to the other treatments, citric acid showed a reduced degree of browning and a comparatively lower pH value (Kanlayanarat, 2003). significantly reduced the amount of grey mold on several plant hosts and demonstrated excellent efficacy in managing *B. cinerea* infection on snap bean pods (Abdel-Rahman, 2015).

Many organic lipophilic acids and inorganic salts, as well as their salts, have antibacterial qualities and could be useful postharvest therapies for decay prevention. A few of these materials are used in the food processing sector (El-Mougy *et al*., 2008; Abd-El-Kareem *et al.,* 2015; Abd-El-Kareem and Saied 2015; Elshahawy *et al*., 2015 and Soliman *et al*. (2021).

Abdel-latif *et al*. (2011) discovered that guava fruits treated with salicylic or citric acids pre harvest showed the greatest reduction in rot disease incidence and severity when stored at room temperature. However, after 15 days of cold storage, no infection was observed in fruits treated with salicylic acid.

Kamara *et al*. (2016) assessed the effectiveness of specific resistance inducers, such as calcium chloride, methyl jasmonate, and salicylic and abscisic acids, in enhancing pepper fruits' resistance to the gray mold fungus (*Botrytis cinerea*) in a lab conditions. According to the results, calcium chloride was the most effective since it reduced the width of the rotting region with a mean of 40.6%. Salicylic acid came in second, while methyl jasmonate and abscisic acid exhibited lower mean inhibition values.

Abd-El-Kareem (2016) according to a study that examined the effectiveness of potassium sorbate and sodium benzoate against postharvest strawberry fruit diseases in vitro, the compounds' respective concentrations of 20.0 and 25.0 g/L were found to inhibit linear growth in *B. cinerea* and *R. stolonifer*.

El-Fawy *et al.* (2020) observed that various chemical food preservatives were evaluated for their ability to prevent strawberry fruit gray mold diseases. Acetic acid, sodium benzoate, benzoic acid, sodium citrate, citric acid, and potassium citrate were the six chemicals whose capacity to inhibit the pathogen's mycelial growth was examined. According to data from in vitro studies, each treatment significantly inhibited the pathogen's mycelial growth.

In order to safeguard human health and shield the soil from the damaging effects of chemical pesticides, it became necessary to protect plants from insects without the use of pesticides as the negative effects of using chemical pesticides to eradicate insect pests in plants increased. Agro fabrics can be used to protect plants from insects without pesticides, such as nylon netting and fine-weave fabrics. Plants are covered with a fine mesh or fabric that allows light and air to pass through, preventing insects from reaching the plants.

The term “agro textiles” refers to woven, nonwoven, and knitted textiles, as well as mesh or foil, that are used for crop or animal cultivation, harvesting, and storage, livestock protection, shading, weed and insect control, and extending the growing season (Basu, 2011). Agro textiles can be separated based on product classification, application area, and production method. Agriculture applications (crop farming), horticulture, floristry, forestry, agro-textiles for cattle breeding, and aquaculture comprise the application field. Agro textiles are made using a variety of production techniques, each of which offers unique structures and capabilities needed for the intended usage (Palamutcu and Devrent, 2017). Both natural and synthetic fibers can be utilized in the creation of agricultural textiles. With the exception of trace amounts of polyester and polyamide fibers, polyolefin fibers are the most widely used synthetic fibers. The fibers that best reflect natural fibers are hemp, flax, sisal, jute, wool, and coir. Because of their high strength, durability, and other advantageous qualities, man-made fibers are frequently employed in the production of agro textiles. However, agro textiles made of natural fibers not only fulfill a specific function but also break down and function as natural fertilizers after a few years.

1.1. Structures for agro-textiles

Different types of textile structures, such as knitted, nonwoven, and woven ones, are utilized depending on their intended function and their specifications (Mansfield, 2005). Among other qualities, these structures are pliable, porous, and permeable to both water and air (Hsieh, 2016).

I. Woven agro-textiles

Special projectile weaving machines are used to create the woven agro-textiles (Basu, 2011). Ground covers, mulch mats, shade cloths, fruit bags, sampling bags, insect-proof, anti-bird, and other items are made from woven fabrics. The woven agro-textiles, which are utilized in many different agricultural applications, such as horticulture and floriculture, aquaculture, forestry, and animal husbandry, play a significant role in protecting silages from environmental damage or attacks by birds and insects (Buyukbayraktar and Bedeloglu, 2020).

II. Non-woven agro-textiles

Natural or synthetic fibers and their mixtures can be used to create nonwoven agro-textiles. Nonwoven can be produced using a variety of methods, the most common being spun bonding and needle punching. While polypropylene is the most popular option for nonwoven agro-textiles created from synthetic fibers, jute is the most commonly utilized natural fiber. Because of its excellent mechanical and functional qualities, availability and processability, environmental compatibility, recyclability, and biodegradability, jute and other biodegradable fibers are being used to make agro-textiles these days. The soil's fertility and health are enhanced by the natural breakdown of the natural-based material. Because biodegradable materials are non-toxic, environmentally benign, and have a minimal influence on the environment, their use in the production of agrotextiles benefits the environment (Agrawal, 2013). Polypropylene fibers are frequently used to make agro-textiles that protect seeds and crops from cold and frost. It is the least expensive type of agro-textile and is mostly used for seedling growth and year-round vegetable growing. It can be placed directly on top of vegetable crops or in a tunnel.

Nonwoven agro-textiles can be utilized to speed up plant development and seed germination, resulting in an earlier harvest and greater yield. Covering seeds and/or plants with nonwoven agro-textile helps to raise the air and soil temperature to an ideal level, which speeds up seed germination and plant growth. In the spring, when seeds are sown or plants are planted, the temperature is not at its ideal level for seed germination or plant growth. Different nonwoven agro-textiles had no or little effect on the amount of radish and carrot seeds that germinated and the time it took for them to do so, but they did speed up the development of potato plants by 19% and 1.3 days, respectively (Fisher, 2013).

Plants are directly covered with spun-bonded non-woven structures to shield them from wind, rain, and frost. Additionally, spun-bonded agro-textiles are used to control insects and birds as well as to cover fruits. Compared to plastic bags, nonwoven bags have the advantage of being breathable, which may keep fruit from freezing in the winter and from decaying in the summer. Punched with a needle (Marasovic, 2019).

III. Knitted agro-textiles

Knitted agro-textiles serve various applications, including screens, packaging materials, antibird nets, fishing nets (Nair and Pandian 2014).

Plant bags made of fabric have advantages over traditional burned clay pots. Agro-textiles also use stitch-bonded, hydro-entangled, thermal-bonded, and wet non-woven materials. Because warp-knitted technology allows for a multitude of designs to meet specific needs, these agro-textiles can be used in a wide range of applications (Scarlat and Pricop 2017).

Basu, (2011) demonstrated that the phrase "agro textiles" refers to woven, nonwoven, and knitted textiles, as well as mesh or foil, that are used for crop, harvesting, and storage, shading, weed and insect control, and extending the growing season.

Using eco-friendly materials to reduce fruit-related fungal infections and using fabrics treated with materials that reduce fungal and insect infections pre and post harvest were the two main goals of this study.

2. Materials and Methods

Chemicals and fabrics:

Nonwoven polyester fabrics with thickness of 0.2mm and weight 26.6g/m^2 were purchased from Egyptian Company CTMC Unengraved Fabric Limited in Suez, sodium bicarbonate, potassium bicarbonate, sodium benzoate and potassium sorbate were grade chemicals of laboratory also organic acids (salicylic, sorbic and benzoic acids) purchased from Merck.

Fungal isolate

The Plant Pathology Department (NRC) in Egypt provided one virulent isolate of the fungi that cause anthracnose disease in mango fruits (*Colletotrichum gloeosporioides*), the green mold disease-causing *Penicillium digitatum*, and the gray mold-causing *Botrytis cinerea*.

Preparation of Alkali and Acids with Different Concentration:

Potassium and sodium bicarbonate, potassium sorbate and sodium benzoate with different concentrations (0.0, 2. 5, 5%) by dissolving the known weight of salt in the determined volume water to obtain the debit concentrations. Also the known weight of organic acids (sorbic, benzoic and salicylic acids) were dissolved in known volume of water to obtain the demand concentration of organic acids

Preparation of spore suspension

The standard inoculum was prepared by cultivating isol*ates of Penicillium digitatum, Colletotrichum gloeosporioides, and Botrytis cinerea*on PDA plates for 10 days at 20 ± 2°C. The culture's surface was brushed with 10 mL of sterile distilled water per plate to create spore suspension. After that, muslin was used to filter the spore suspensions. The concentration of spore suspension was reduced to about 106 spore/mL using a hemocytometer slide.

Treatment of fabric disks with different chemicals

Nonwoven fabric disks of 0.2 mm were dipped in a specific concentration of the chemicals under test for 30 minutes, and then allowed to air dry at room temperature for zero, one, six, and twelve hours.

Testing of different organic acids on inhibition zone of pathogenic fungi

Salicylic, sorbic, and benzoic acids three organic acids were examined at concentrations of 0.0, 2.5, and 5.0%. Sterilization-treated fabric disks were utilized as test substance carriers. As previously stated, inoculation plates and treated fabric disks were used.

Testing of different salts on inhibition zone of pathogenic fungi

Four salts potassium bicarbonate, sodium benzoate, sodium bicarbonate and potassium sorbate at three different concentrations 0.0, 2.5, and 5.0% were examined. Sterilization-treated fabric disks were utilized as test substance carriers. As previously stated, inoculation plates and treated fabric disks were used.

1. Frist experiment

***In vivo* experiments**

Testing of different promising treatments for controlling fruit diseases

Mango and orange fruits were studied to see how they affected apple fruit diseases. Salicylic acid, benzoic acid, and sodium bicarbonate were chosen to investigate their effects on orange fruit green mold, apple fruit gray mold, and mango fruit anthracnose *in vivo.*

Testing of promising treatments on green mold disease of orange fruits

The National Research Center station provided the Valencia orange fruits used in the experiment. They were chosen for their uniformity, size, color, and shape as well as the absence of fungal infections.

Fungal isolate

One isolate of *Penicillium digitatum* Sacc. that is virulent. the causal agents of green mold disease of citrus fruits were obtained from Plant Pathol. Dept., (NRC).

Preparation of spore suspension

Penicillium digitatum spore suspension was prepared as mentioned before

Effect on green mold disease of Valencia orange

Sodium bicarbonate and benzoic acid at a 5.0% concentration were tested to see how they affected Valencia orange fruit green mold *in vivo.* The Valencia orange fruit's surface was treated with 70% ethanol for two minutes at room temperature, and then it was repeatedly cleaned in sterile water. The fruits have fictitious wounds made in them with a sterilized scalpel.

Treatment of fabric materials with different chemicals

Individual 23 x 30 cm pieces of fabric were dipped in the prior treatments for 30 minutes each, and then allowed to air dry for 12 hours at room temperature.

Covered wounded fruits with treated Fabric and fruits inoculation

Wounded fruits were covered with treated fabric.

Covered fruits were sprayed with a suspension of *Penicillium digitatum* spores (106 spores/ml) and let to air dry in order to inoculate them.

A collection of fruits was covered with fabric soaked in sterile water as a control. To be evaluated, all treated or untreated (control) fruits were packed into carton boxes at a rate of 10 fruits per box and kept in storage for 15 days at a temperature of 20–2°C and a relative humidity of 90–95%. Fruits were periodically inspected for green mold infection.

Assessment of green mold disease

Chen *et al.* (2016) used a modified scale to score the severity of the disease in each fruit, whereas disease incidence (%) was reported as the percentage of fruit affected from 0 to 4 as: 0 = No symptoms; 1 = Less than 25%; 2 = 26 to 50%; 3 = 51 to 75 % and 4= more than 76 % of fruit surface showing symptoms.
Percentage of disease severity was calculated from the disease rating by the formula:

$$\text{Disease Severity \%} = \frac{\Sigma \text{ Rating no.} \times \text{the no. of fruits}}{\text{Total no. of fruits}} \times 100$$

Statistical analysis

Tukey test for multiple comparison among means was utilized Neler *et al.* (1985).

2. Second Experiment

Testing of promising treatments on gray mold disease of apple fruits

The National Research Center station provided the apple fruits (cv Anna) used in the experiment. In addition to their lack of fungal infections, they were selected based on their consistency, size, color, and shape.

Fungal isolate

*Botrytis cinerea*the cause of gray mold, of apple fruits were obtained from Plant Pathol. Dept., (NRC). The pathogenic isolates were maintained on potato dextrose agar PDA for further study.

Preparation of spore suspension

Spore suspension was obtained by flooding 2-week-old cultures of *Botrytis cinerea* with sterile distilled water that contained 0.1% (v/v) Tween 80. A hemacytometer instrument was used to count the spores, and sterile distilled water was used to adjust the pathogens' spore concentrations to 1×10^6 spores/ml.

Effect on gray mold disease of apple fruits

Salicylic acid Benzoic acid and Sodium bicarbonate at concentration of 5.0% were evaluated to determine their impact on gray mold disease of apple fruits *in vivo*. With ethanol 70 % applied to the apple fruits surface for 2 minutes at room temperature and repeatedly washed in sterilized water. Using a sterile scalpel, fake wounds were created in the fruits.

Treatment of fabric materials with different chemicals

Fabric materials (23 x 30 cm) were dipped individually in previous treatments for 30 min. then air dried at room temperatures for 12 hours.

Covered wounded fruits with treated Fabric and fruits inoculation

Wounded fruits were covered with treated fabric.

Inoculation of covered fruits was carried out by spraying fruits with a suspension of *Botrytis cinerea* spores (10^6 spores/ml) and letting them air dry.

As a control, a group of fruits were covered with fabric treated with sterilized water that were used. To be evaluated, all treated or untreated (control) fruits were packed into carton boxes at a rate of 10 fruits per box and kept in storage for 15 days at a temperature of 20–2°C and a relative humidity of 90–95%. Fruits were periodically inspected for green mold infection.

Disease severity (%) was reported as the percentage of fruit infected, which was determined using the following formula, whereas disease incidence (%) was defined as the proportion of fruit infected:

$$\text{Percentage of rotted part (\%)} = \frac{\text{Rotted part weight of fruit}}{\text{Fruit weight}} \times 100$$

3. Third Experiment
Testing of promising treatments on anthracnose disease of mango fruits
Pathogenic fungus

Colletotrichum gloeosporioides, the fungi causing fruit anthracnose disease of postharvest mango fruits were obtained from Plant Pathol. Dept., (NRC). The pathogenic isolates were maintained on potato dextrose agar PDA for further study.

Mango fruits

The mango fruits cv. Ewesy were obtained from National Research Centre station. They were chosen for their uniformity, size, color, and shape as well as the absence of fungal infections.

Inoculum preparation

*Colletotrichum gloeosporioides*the cause of anthracnose disease on mango fruits Spore suspension was obtained by flooding 2-week-old cultures of *Colletotrichum gloeosporioides* with sterile distilled water that contained 0.1% (v/v) Tween 80. Spores were counted using a hemacytometer slid, and the spore concentrations from the pathogens were adjusted with sterile distilled water to obtain 1 × 106 spores / ml.

Effect on anthracnose disease of mango fruits

Salicylic acid Benzoic acid and Sodium bicarbonate at concentration of 5.0% were evaluated to determine their impact on anthracnose disease of mango fruits in vivo. With ethanol 70 % applied to the apple fruits surface for 2 minutes at room temperature and repeatedly washed in sterilized water. Using a sterile scalpel, fake wounds were created in the fruits.

Treatment of fabric materials with different chemicals

Fabric materials (23x30 cm) were dipped individually in previous treatments for 30 min. then air dried at room temperatures for 12 hours.

Covered wounded fruits with treated Fabric and fruits inoculation

Wounded fruits were covered with treated fabric. Inoculation of covered fruits was carried out by spraying fruits with a suspension of *Colletotrichum gloeosporioides* spores (106 spores/ml) and letting them air dry. As a control, a group of fruits were covered with fabric treated with sterilized water that were used. To be evaluated, all treated or untreated (control) fruits were packed into carton boxes at a rate of 10 fruits per box and kept in storage for 15 days at a temperature of 20–2°C and a relative humidity of 90–95%. Fruits were periodically inspected for green mold infection.

The percentage of infected fruits to total fruits was used to calculate the disease incidence. On mango fruits, the disease severity (0–5) is used to determine the percentage of fruit infected with anthracnose disease (Rose, 1974).0= zero infection, 1= 1-10, 2= 11-25, 3=26-50, 4= 51-75 and 5 more than 75 percent of fruit area infected.

The percent disease index was recorded with the following formula as given by Rose (1974).

$$\text{Percent Disease Index(PDI)} = \frac{\text{Sum of all individual rating}}{\text{Total number of fruits grate x Maximum disease grate}} \text{x100}$$

Statistical analysis

Tukey test for multiple comparison among means was utilized (Neler *et al.,*1985).

3. Results

Effect of different organic acids on inhibition zone of pathogenic fungi

The growth inhibition zone of *Penicillium digitatum, Botrytis cinerea,* and *Colletotrichum gloeosporioides* was tested against three organic acids salicylic, sorbic, and benzoic acids at concentrations of 0.0, 2.5, and 5.0%. Table 1 and Fig1 showed that the inhibition zones for *Penicillium digitatum, Botrytis cinerea,* and *Colletotrichum gloeosporioides* were more than 11.0, 10.0, and 9.0 mm for salicylic, sorbic, and benzoic acids at 5.0%, respectively.

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Table 1: Effect of different organic acids on inhibition zone of pathogenic fungi

Organic acids	Conc.%	Inhibition zone (mm)		
		Penicillium digitatum	***Botrytis cinerea***	***Colletotrichum gloeosporioides***
Benzoic	2.5	6.1b	5.0c	4.0b
	5.0	12.0a	10.0a	8.0a
Salicylic	2.5	4.5b	4.0c	4.0b
	5.0	13.0a	11.0a	10.0a
Sorbic	2.5	5.4b	3.9c	3.9b
	5.0	11.0a	10.0a	9.0a
Control (sterilized water)	0.0	0.0c	0.0d	0.0 c

- Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

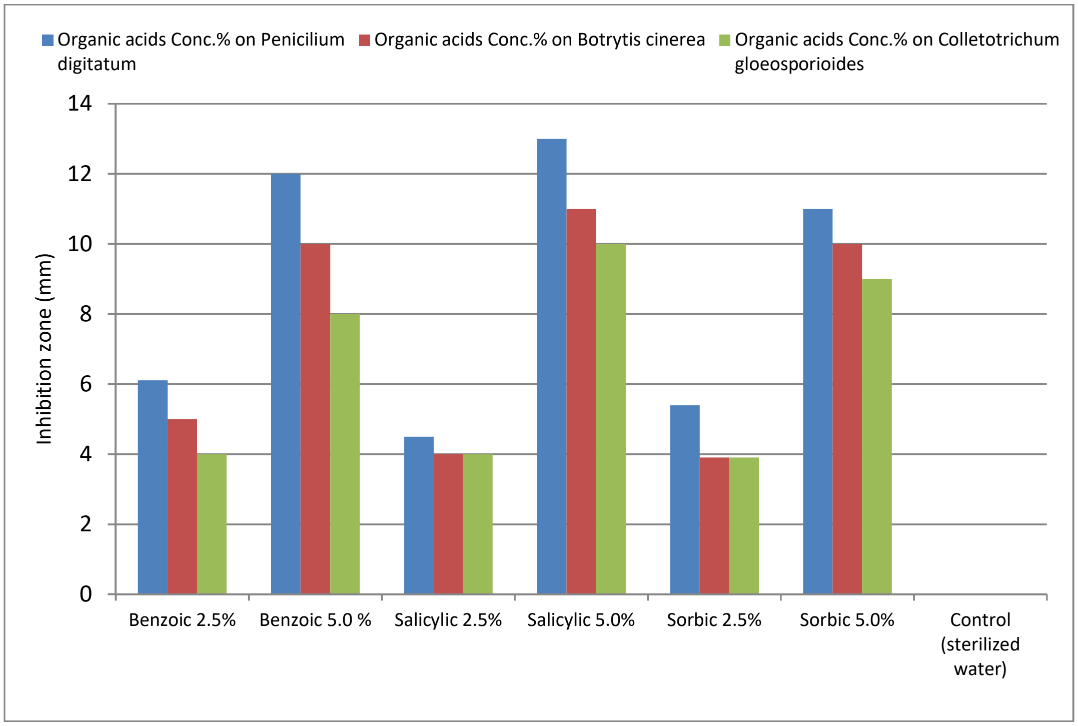

Fig. 1: Effect of different organic acids on inhibition zone of pathogenic fungi

Effect of different salts on inhibition zone ofpathogenic fungi

Colletotrichum gloeo sp orioides and *Botrytis cinerea* were examined for their impact on the inhibition zone of *Penicillium digitatum*. Four salts *i.e.* Sodium benzoate, Potassium sorbate, Sodium bicarbonate and Potassium bicarbonate at three concentrations, 0.0, 2.5 and 5.0 %, were investigated. All tested salts considerably recorded the inhibitory zone of all rested fungus, according to the results in Table (2) and Fig 2. With sodium bicarbonate at 5.0%, the inhibitory zone increased the most, measuring 11.0, 9.0, and 8.0 mm for *Penicillium digitatum, Botrytis cinerea, and Colletotrichum gloeosporioides*, respectively. The effects of other salts were mild.

Table 2: Effect of salts inhibition zone of pathogenic fungi

Salts	Conc. %	Inhibition zone (mm)		
		Penicillium digitatum	***Botrytis cinerea***	***Colletotrichum gloeosporioides***
Sodium benzoate	2.5	6.1c	6.1c	4.1c
	5.0	6.0c	6.0c	5.0b
Potassium sorbate	2.5	4.5d	4.0d	2.0e
	5.0	7.0b	8.0a	4.0c
Sodium bicarbonate	2.5	5.0d	6.0c	5.0b
	5.0	11.0a	19.0a	8.0a
Potassium bicarbonate	2.5	2.4e	4.0d	3.0d
	5.0	10.0a	7.0b	8.0a
Control (sterilized water)	0.0	0.0f	0.0 e	0.0f

- Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

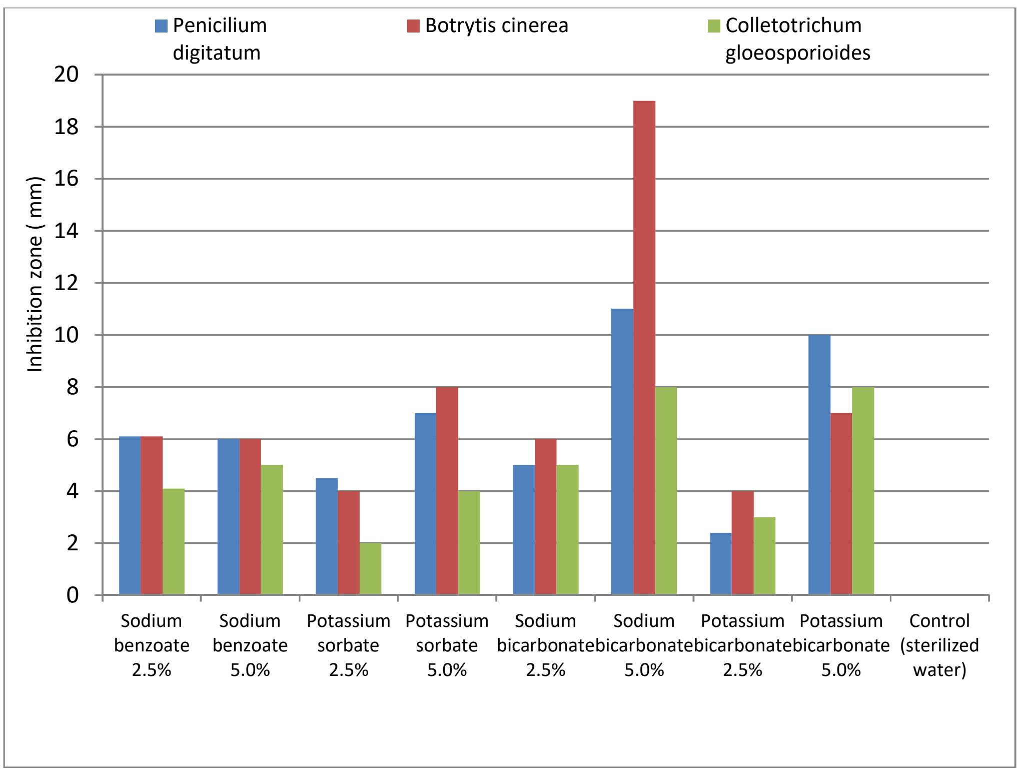

Fig. 2: Effect of salts inhibition zone of pathogenic fungi

In vivo experiments
Effect of different promising treatments for controlling fruit diseases

The effects of salicylic acid, benzoic acid, and sodium bicarbonate at a dosage of 5.0% on orange fruit green mold, apple fruit gray mold, and mango fruit anthracnose were investigated *in vivo* (Fig. 3).

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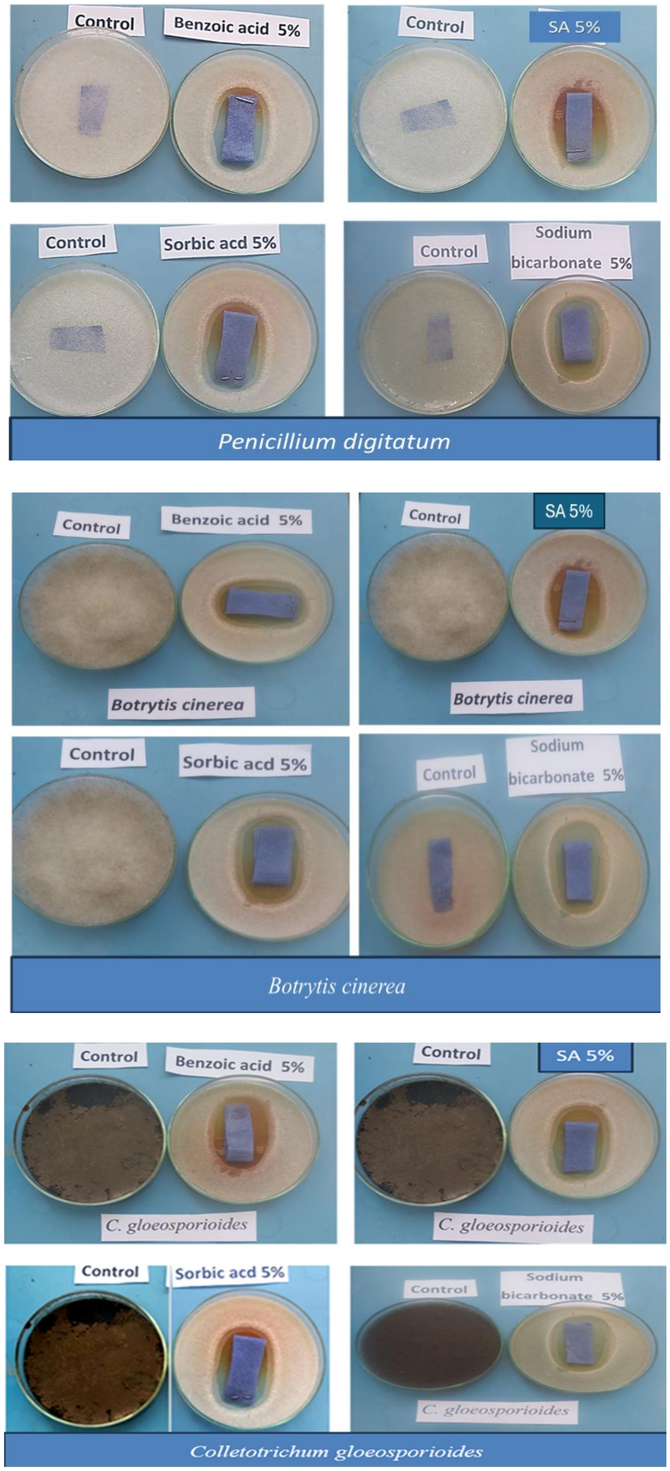

Fig. 3: Effect of different organic acids and salts on inhibition zone of pathogenic fungi

Effect of promising treatments on green mold disease of orange fruits

The green mold disease in Valencia orange fruits was considerably decreased by all tested treatments, according to the results in Table 3 and Figs. 4,5 with salicylic acid and benzoic acid, the incidence and severity of the disease were completely suppressed. In the meantime, sodium bicarbonate decreased the severity and incidence of the condition by 45.0% and 60.0, respectively.

Table 3: Effect of promising treatments on green mold disease of Valencia orange fruits(1) covered with treated fabric

Promising treatments	Green mold of Valencia orange fruits			
	Disease incidence	Efficacy %	Disease severity	Efficacy %
Salicylic acid (5%)	00.0(2)	100.0	00.0	100.0
Benzoic acid (5%)	00.0	100.0	00.0	100.0
Sodium Bicarbonate (5%)	40.0	60.0	55.0	45.0
Control (un-treated)	100.0	00.0	100.0	00.0

[1]Fruits were wounded, covered with treated fabric and inoculated with pathogenic fungus, then stored at 20^{0}C for 21 days.
[2]Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

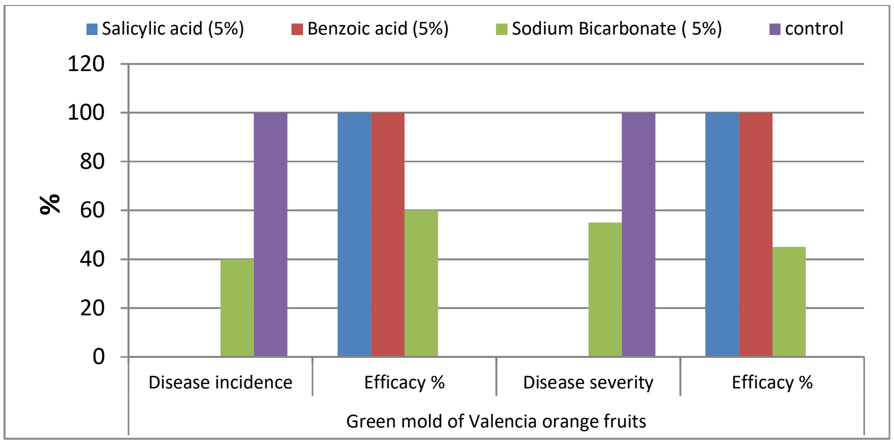

Fig. 4: Effect of promising treatments on green mold disease of Valencia orange fruits(1) covered with treated fabric

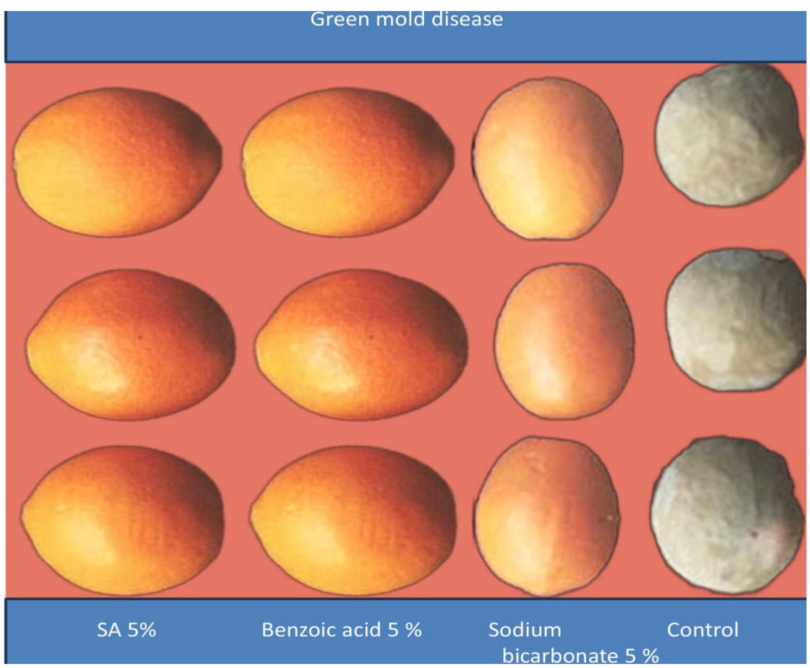

Fig. 5: Effect of promising treatments on green mold disease of navel orange fruits covered with treated fabric**.**

Effect of promising treatments on gray mold disease of apple fruits

Results in Table (4 and Figs. 6,7) reveal that all tested treatments significantly reduced the gray mold disease of apple fruits. Complete suppression of disease incidence and severity was obtained with Salicylic acid, Benzoic acid. Meanwhile, Sodium bicarbonate reduced the disease incidence and severity by 70.0 and 55.0% respectively.

Table 4: Effect of promising treatments on gray mold disease of apple fruits[1] covered with treated fabric

Promising treatments	Gray mold of apple fruits			
	Disease incidence	Efficacy %	Disease severity	Efficacy %
Salicylic acid (5%)	00.0[2]	100.0	00.0	100.0
Benzoic acid (5%)	00.0	100.0	00.0	100.0
Sodium Bicarbonate (5%)	30.0	70.0	45.0	55.0
Control (un-treated)	100.0	00.0	100.0	00.0

[1]Fruits were wounded, covered with treated fabric and inoculated with pathogenic fungus, then stored at 200Cfor 21 days.
[2]Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

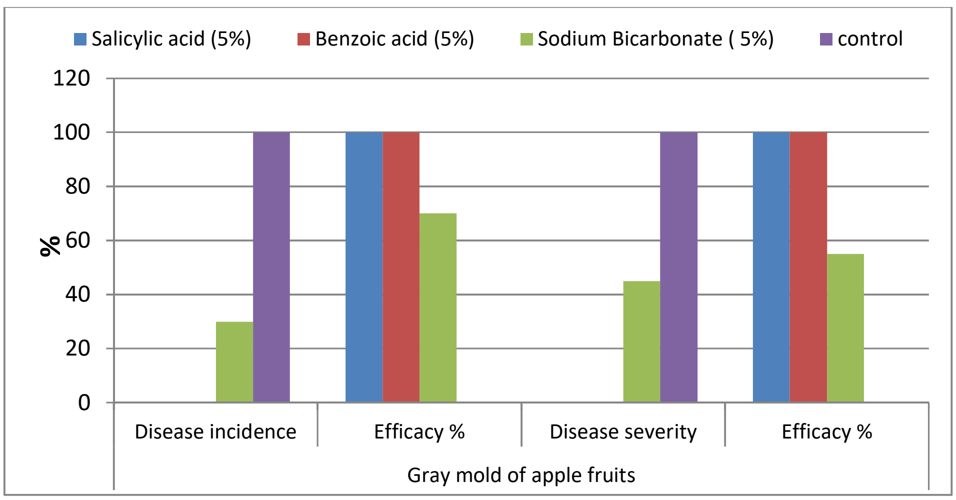

Fig. 6: Effect of promising treatments on gray mold disease of apple fruits covered with treated fabric.

Fig. 7: Effect of promising treatments on gray mold disease of apple fruits covered with treated fabric

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Effect of promising treatments on anthracnose disease of mango fruits

The anthracnose disease of mango fruits was considerably decreased by all investigated treatments, according to the results in Table (5 and Figs 8,9). With salicylic acid and benzoic acid, the incidence and severity of the disease were completely suppressed. In the meantime, sodium bicarbonate decreased the severity and incidence of the condition by 55.0% and 70.0, respectively.

Table 5: Effect of promising treatments on anthracnose disease of mango fruits(1) covered with treated fabric

Promising treatments	Anthracnose of mango fruits			
	Disease incidence	Efficacy %	Disease severity	Efficacy %
Salicylic acid (5%)	00.0(2)	100.0	00.0	100.0
Benzoic acid (5%)	00.0	100.0	00.0	100.0
Sodium Bicarbonate (5%)	55.0	45.0	50.0	50.0
Control (un-treated)	100.0	00.0	100.0	00.0

[1]Fruits were wounded, covered with treated fabric and inoculated with pathogenic fungus, then stored at 20^0 C for 21 days.
[2]Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$).

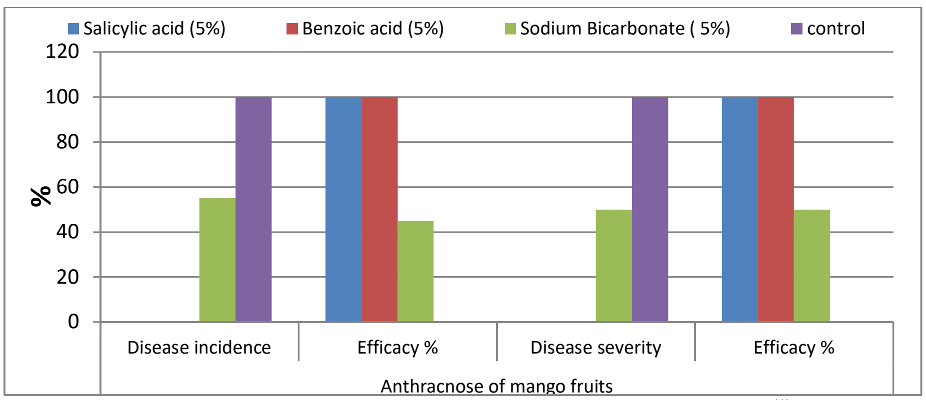

Fig. 8: Effect of promising treatments on anthracnose disease of mango fruits(1) covered with treated fabric.

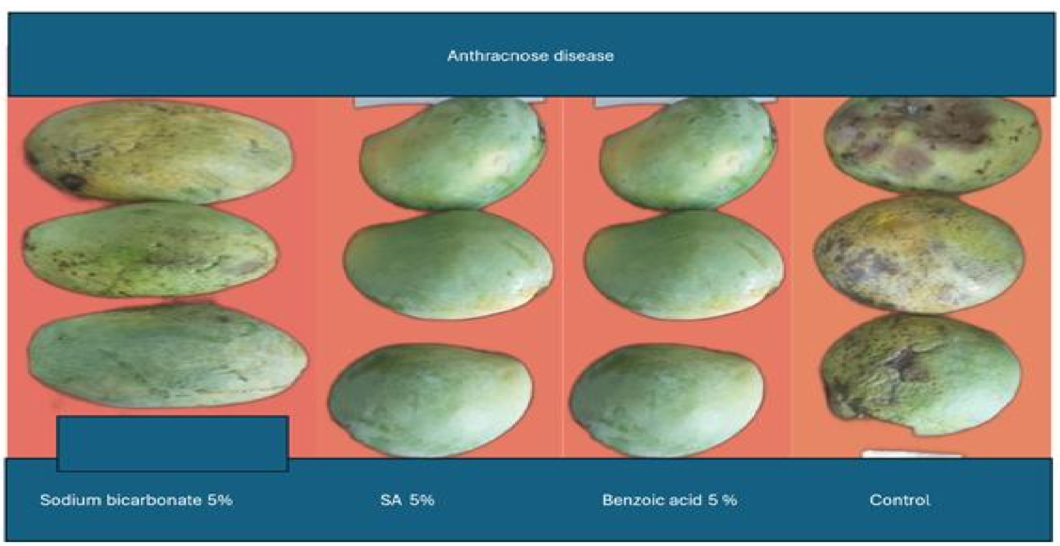

Fig. 9: Effect of promising treatments on anthracnose disease of mango fruits covered with treated fabric

4. Discussion

Fruit losses during pre and postharvest handling considerably decreased the overall fruit production. There are a number of reasons for this, but inadequate product handling where mechanical damage and pathogen caused diseases are major contributors is one of the most significant (Carmona-Hernandez, *et al.,* 2019 and Abd-El-Kareem *et al.*, 2022).

It is necessary to investigate new, secure, and effective alternatives for controlling postharvest diseases (Abd-El-Kareem and Saied, 2015; Abd-El-Kareem *et al.,* 2015, 2022).

Salts, both inorganic and organic, exhibit a wide range of activity against a variety of fungus. They are also affordable, simple to use, safe for both people and the environment, and appropriate for commercial postharvest handling procedures (El-Mougy *et al*., 2008 and Youssef and Hussien, 2020).

Salicylic, sorbic, and benzoic acids at 5.0% recorded the inhibitory zone more than 11.0, 10.0, and 9.0 mm for *Penicillium digitatum, Botrytis cinerea*, and *Colletotrichum gloeosporioides*, respectively, according to the results of the current study's *in vitro* studies.

The highest increase of inhibition zone was obtained with Sodium bicarbonate at 5.0% which recorded 11.0, 9.0 and 8.0 mm for *Penicillium digitatum, Botrytis cinerea* and *Colletotrichum gloeosporioides* respectively. Other salts showed moderate effects.

Additionally, *in vivo* tests were conducted to examine the effects of sodium bicarbonate, benzoic acid, and salicylic acid at a concentration of 5.0% on orange fruit green mold, apple fruit gray mold, and mango fruit anthracnose.

Results indicated that all tested treatments significantly reduced the all tested diseases. Complete suppression of all tested diseases (incidence and severity) was obtained with Salicylic acid, Benzoic acid at concentration of 5.0 %. Meanwhile, moderate effect was obtained with Sodium bicarbonate. In this respect, El-Mougy *et al*. (2008) investigated controlling postharvest diseases caused by *Geotricumcandidum* (sour rot), *Penicillium digitatum* (green mold), and *P. italicum* (blue mold) using (ascorbic, benzoic, citric and sorbic acids) as well as (potassium sorbate and sodium benzoate salts). They stated that exposure to benzoic, citric, and sorbic acids, as well as to sodium benzoate or potassium sorbate, completely inhibited the linear development of all examined fungus. Additionally, Mohamed *et al.* (2015) investigated the *in vivo* control of two fungal infections that target snap bean pods of the cvs. Xera and Valentino using five organic acids: ascorbic, citric, boric, salicylic, and acetic. When compared to those treated with citric and salicylic acids, those treated with boric, acetic, and ascorbic acids exhibited the least amount of *B. cinerea* induced deterioration.

Gray mold development was reduced in lab settings when pepper fruits were treated with salicylic acid (SA) and abscisic acid as resistance inducers (Kamara *et al.,* 2016).

Salicylic acid (SA) is a phenolic hormone that plays a crucial role in stress resistance in plants. Pre and post-harvest spraying with SA achieved high control against pathogens in pear (Jiankang *et al*., 2006), It also caused control in sweet cherry through induction of the defense resistance system (Yao *et al*., 2005) and stimulated antioxidant enzymes (Xu and Tian, 2008). When SA was sprayed on *Capsicum frutescens*, peroxidase activity rose while catalase activity remained close to the negative control (Amin *et al.*, 2009).

Salicylic acid is an important signaling molecule involved in both locally and systemically induced disease resistance responses. The ability to accumulate salicylic acid has been shown to be essential for systemic acquired resistance and reactions to abiotic stress in plants (Kubota and Nishi 2006; Morse *et al.,* 2007; Zawoznik *et al.,* 2007 and Fawzy, 2013).

Sorbic acid and its salts can inhibit microorganisms through a variety of mechanisms, including changes in cell transport function, inhibition of enzymes involved in the tricarboxylic acid cycle or glycolytic pathway through inhibition of RNA, DNA, and protein synthesis, and uncoupling of mitochondrial oxidative phosphorylation (Sofos *et al.,* 1986 and Sofos, 1992). The depletion of ATP was reported in conidia of various molds fungi after exposure to sorbic acid (Cheng and Piper, 1994). The very low levels of mammalian toxicity of potassium sorbate (LD_{50} in rate: 4 - 7 g/kg body weight, equals 500 g for an adult human) and its wide application as a food preservative proved it excellent suitable for postharvest treatment (Cheng and Piper, 1994).

Additionally, postharvest treatments with salt preservatives, specifically sodium benzoate (SB) and potassium sorbate (PS), against *Penicillium digitatum* and *P. italicum*, the causative organisms of Valencia orange fruit green and blue mold, respectively, were assessed, according to Elshahawy *et al.* (2015).

In vitro studies, complete inhibition of both linear mycelial growth and conidial germination of both *P. digitatum*and *P. italicum*was obtained with (SB) at 20 g/L and (PS) at 15 g/L. The results showed that, in comparison to the control, all treatments considerably decreased the incidence (%) and severity (%) of Valencia orange, green, and blue mold.

Additionally, Abd-El-Kareem (2016) reported that in vitro trials showed that potassium sorbate and sodium benzoate, at concentrations of 20.0 and 25.0 g/L for *B. cinerea* and *R. stolonifer*, respectively, produced competitive suppression of linear growth.

Several inorganic salts and organic acids and their salts, some of which are used, in the food processing industry, have antimicrobial properties and could be useful as postharvest treatment for decay control (El-Mougy *et al*., 2008; El-Shahawy *et al*., 2015; Abd-El-Kareem *et al,* 2015; Abd-El-Kareem and Saied 2015 and Soliman *et al*. (2021).

According to El-Fawy *et al.* (2020), certain chemical food preservatives have been evaluated for their ability to prevent gray mold diseases in strawberry fruits. The ability of six substances to stop the pathogen's mycelial growth was tested: acetic acid, sodium benzoate, benzoic acid, sodium citrate, citric acid, and potassium citrate. Data from *in vitro* investigations revealed that every therapy considerably slowed the pathogen's mycelial development.

Conclusion

It could be concluded that using agro-textiles treated with eco-friendly materials reduces pre- and post-harvest diseases on fruits. As well as enhance the quality and shelf life of the produce and promote sustainable agricultural practices that can benefit both farmers and consumers. By implementing these innovative solutions, we can strive for a more resilient food system that reduces environmental impact. Additionally, the findings from this research could pave the way for further advancements in crop management strategies, leading to improved yields and reduced reliance on harmful herbicides and pesticides.

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