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Antifungal Activity of Acetic Acid Applied as Volatile or Carrier Contact Assay to Management Storage Fungi of some Medicinal and Aromatic Seeds

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ABSTRACT

The most significant medicinal and aromatic plants in Egypt and the rest of the globe are caraway, cumin, and anise. Many fungi, including Aspergillus flavus, Aspergillus niger, and Fusarium verticillioides, attack and harm them after harvest and while they are being stored. At 7.5 µl/l, AA vapor suppressed the linear growth and spore germination of *A. flavus* and *F. verticillioides*, while 9.0 µl/l inhibited *A. niger*. AA solution at 0.75/L completely suppressed the mycelial growth and spore germination of *A. flavus* and *F. verticillioides*, while at 1.0 ml/L inhibited linear growth and spore germination of *A. niger*. Two methods *i.e.* Volatile assay (AA vapor) and Carrier contact assay (wheat bran carrier) were tested to suppress fungal infection of some medicinal and aromatic seeds. As for volatile assay results showed that complete suppression of natural infection was obtained with AA at 250 ml /L. Followed by AA at 200 ml/L which reduced the natural infection by 77.0,80.0 and 79.0% for cumin, anis and caraway seeds respectively. Complete suppression of germination was obtained with AA at 250 ml /L. As for Carrier contact assay complete suppression of natural infection was obtained with AA at 25g/kg seeds. Followed by AA at 20 g/kg seeds ml/L which reduced the natural infection by 75.0,88.0 and 90.0% for cumin, anise and caraway seeds respectively. Complete suppression of germination was obtained with AA at 25 g/kg seeds.

Keywords: Medicinal and aromatic seeds, Acetic acid, Storage fungi.

1. Introduction

The most significant medicinal and aromatic plants in Egypt and the world are fennel (*Foeniculum vulgare* L.), caraway (*Carum carvi* L.), anise (*Pimpinella anisum* L.), cumin (*Cuminum cyminum* L.), and coriander (*Coriandrum sativum* L.). *Aspergillus* species, *Penicillium* species, *Rhizopus* species, and *Fusarium* species are among the many fungus that attack and harm them after harvest and while they are being stored (Moharram *et al.,* 1989 and Regina and Roman 1992). In traditional medicine, cumin is used as a carminative for colic, diarrhoea, and stomach issues (Parthasarathy *et al.,* 2008). The seeds contain 2-5 % essential oil, the major ingredient of which is cuminaldehyde (Hassan *et al.,* 2014).

Said and El-Hady Goder (2014) reported to evaluate fungus colonies in anise and cumin seed storage. The total fungal population often displayed erratic monthly changes with certain peaks mainly due to the breakouts in the counts of A. flavus, A. fumigatus, A. niger, A. sydowii and Mucor hiemalis.

According to Abd-Alla (2005) assessment of common storage fungi of several aromatic and medicinal seeds, such as fennel, cumin, coriander, and anise, *Aspergillus niger* and *Penicillium* sp. were the most prevalent fungus linked to storage seeds. With the exception of *Penicillium* sp. anise seed, *A. niger* ranked highest among all examined seeds.

In traditional medicine, anise (*Pimpinella anisum* L.) seeds are used to alleviate migraines. The essential oils from anise seeds, mainly anethole, were extracted. Antibacterial, antifungal, insecticidal,

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antiviral muscle relaxant, antispasmodic and smooth muscle relaxant, anticonvulsant, antiulcer, antidiabetic, hypolipidemic, and pain alleviation in dysmenorrhea are only a few of the pharmacological investigations on anise that have been published (Mostafa *et al.,* 2023).

Caraway essential oil has antimicrobial activities against pathogens such as Staphylococcus aureus, Salmonella, Candida Albicans. Likewise, thanks to the polyphenols it contains, it induces an increase in the production of antioxidant enzymes such as SOD, CAT, GSH, glutathione and a reduction in the proliferation of defective or even cancerous cells (Mahboubi, 2019 and Ahmed *et al*., 2020).

Both plants and animals contain acetic acid, a universal metabolic intermediate (Busta and Foegeding, 1983). Food manufacturers frequently employed it as an acidulent or antimicrobial preservative in a range of food products (Davidson and Juneja, 1990 and Abdallah 2005). AAfumes were very successful in eliminating postharvest fungal spores that cause a variety of fruits to deteriorate (Sholberg *et al.,* 1998).

Several fruits did not postharvest deteriorate when fumigated with acetic acid (Sholberg and Gaunce 1995, Sholberg and Gaunce, 1996b, Sholberg *et al.,* 1996; Sholberg *et al.,* 1998 and Abdallah 2005). At concentrations of 8 and 10 µl/l, AAvapours completely suppression of mycelial growth and spore germination of *B. cinerea* and *R. stolonifer*, the causal agents of strawberry soft and gray rots, according to Morsy *et al.,* (1999). Additionally, they found that AA vapours decreased the incidence of strawberry postharvest diseases. Artificially infected several cereal seeds with A. flavus were successfully protected from infection by applying AA vapors (Sholberg and Gaunce, 1996a).

Cereal seed treatments using acetic acid fumes have been developed (Sholberg *et al.,* 2006). According to preliminary experiments, acetic acid fumes could lower viable *F. graminearum* populations in seeds without influencing seed germination (Pouleur *et al.,* 2008). A higher dosage might work better, even if this treatment had less of an impact on *B. sorokiniana.* According to Morsy *et al.,* (2000a and b), acetic acid fumes at a concentration of 8 l/l completely inhibited the spore germination and linear growth of every investigated fungus. All grains, with the exception of millet, which required 0.300 ml/l, had their natural infection completely inhibited when fumigated with acetic acid vapor at a rate of 0.250 ml/l. Rioux *et al.* (2016) the three non-chemical treatments lowered the contamination rate for all Fungal contaminated lots below the 15% rejection threshold, which is the Danish recommendation for Fusarium spp. AAV-H was the most effective at reducing contamination in Bs-contaminated lots, followed by AAV-L and dry heat, which had no effect on barley.Acetic acid has also been used to manage plant diseases, especially those caused by fungus that are carried in seeds, due to its well-known antifungal and antibacterial properties. In wheat, acetic acid seed treatment has been demonstrated to successfully inhibit common bunt and leaf stripe (Borgen and Nielsen, 2001; Saidi *et al.,* 2001 and Sholberg *et al.,* 2006). According to Dorna *et al.,* (2021), acetic acid applied to carrot seeds effectively lowers Alternaria spp. without impairing seed germination (Dorna *et al.,* 2018).

Thyme and acetic acid were used to prevent the mycelial growth of storage fungi of maize grains, according to Haggag-Wafaa *et al.,* (2024). notable effect on the suppression of spore germination and mycelial development in both isolates of *A. flavus*. Thyme and acetic acid were successful in lowering AFB1 while totally inhibiting the generation of AFB2, which meant that they were effective in inhibiting aflatoxin synthesis in both the vapour and carrier contact assays used for postharvest application treatments.

Saied-Nehal, (2024) reported that impact of AA fumigation on mycelial growth and spore germination of common storage fungi, as well as their curative and protective effects in the control of storage diseases in some commercial grains, was examined. All tested concentrations significantly reduced natural infection in all tested grains. Natural infection was completely suppressed by AA at 0.250 ml/L for wheat and maize, and 0.300 ml/L for barley grain. At 0.200 mL/L, AA reduced natural infection by 86.0, 91.0, and 66.0% in wheat, maize, and barley, respectively.

This study aims to investigate the impact of AA applied as Volatile or Carrier Contact Assay against storage fungi of some medicinal and aromatic seeds.

2. Materials and Methods

Cumin (*Cuminum cyminum* L.), caraway (*Carum carvi* L.) and, anise (*Pimpinella anisum* L.) were obtained from commercial markets.

2.1. Storage fungi

One pathogenic isolate of *Aspergillus flavus* (Accession number: OQ135182.1), *Aspergillus niger* (Accession number: OQ135183.1) and *Fusarium verticillioides* (Accession number: OQ135185.1) which was also known as *Fusarium moniliforme* were maintained and supplied by (Dr. Al-Ansary- Noran, (2023). Plant Patholology Department, National Research Centre (NRC) Giza, Egypt.

2.2. Fumigation

AA treatment was applied in especial chamber with a 270 L volume and a fan to provide a closed circulating air current (Morsy *et al.,* 2000).

- **Impact of AA applied as volatile or Carrier Contact Assay on: -**
- Storage fungal linear growth.
- Storage fungal spore germination.
- Natural infection of some medicinal and aromatic Seeds.
- Percentage of grain germination.

2.3. Impact of AA vapors on storage fungal mycelia growth

Disks containing 10-day-old cultures of *A. flavus*, *A. niger*, and *F.verticillioides* were treated with AA vapours at 2.5, 5.0,7.5 and 9.0 µl/l (v/v) for 30 minutes. In Petri dishes, treated discs were moved to PDA medium.Untreated disks were used as controls. Mycelial growth was recorded after the untreated plates reached full size. Each treatment was replicated with twenty-five disks.

2.4. Impact of AA vapours on spore germination

Different concentrations of AA i.e. 2.5, 5.0,7.5 and 9.0 µl/l) were chosen. Drops of *A. flavus, A.niger*, and *F. verticillioides* spore suspension were deposited on PDA medium at five spots on plastic Petri plates (10 ml of medium). The inoculation plates were opened, fumigated with AA at the previous concentrations for 30 minutes, and incubated for 24 hours at 25ºC. Spore germination percent was determined using 100 spores four times under a microscope. Spore suspension was placed on PDA medium at five evenly spaced spots on plastic Petri plates (Sholberg and Gaunce 1995)

2.5. Impact of AA solutions on mycelia growth and spore germination of storage fungi.

Different volumes of analytically pure AA(CH_3COOH -99.99%) were added to 250 ml conical flasks that held 100 ml of sterilised PDA medium each in order to achieve concentrations of 0.25, 0.50, 0.75, and 1.0 ml/l. After that, it was gently rotated and poured into Petri dishes with a diameter of 10 cm. Equal discs (6 mm in diameter) of fungal growth, extracted from a 10-day-old culture cultivated on PDA media and kept at 20°2°C, were seeded individually in the center of each dish. When the control plates reached full growth, the tested fungal mycelial growth was assessed. For each specific treatment, four replicates were used.

As for spore germination, conidia from 10 5 days old tested fungi were collected, then placed in sterile water to create a spore suspension that was adjusted to 106 spores per millilitre. Petri plates were filled with aliquots of the prepared spore suspension. Plates were filled with PDA media containing acetic acid to achieve final concentrations of 0.25, 0.50, 0.75, and 1.0 ml/L. As a comparison, a set of plates with PDA media devoid of acetic acid was utilized. The plates were incubated for 24 hours at 20°C. For both fungi, the spore germination percentage was computed.

2.6. Application methods

Two application methods *i.e.* Volatile assay (AA vapor) and Carrier contact assay(wheat bran carrier) were tested with the acetic acid at different concentrations to suppress fungal infection of some medicinal and aromatic seeds .

2.7. Volatile contact assay (vapor)

The method of Morsy *et al.,* (2000) was used as cumin anise and caraway seeds were fumigated with AA vapours at 0.050, 0.100, 0.150, 0.200 and 0.250 ml/l for 60 minutes in fumigation in especial chamber with a 270 L volume and a fan to provide a closed circulating air current (Morsy *et al.,* 2000). Treated seeds were added to Petri plates with Czapek's medium (Difco, Detroit, MI) and incubated for 10 days at 25ºC. The percentage of seeds with fungal growth was calculated. Seeds exposed to air current acted as the control.

2.8. Carrier contact assay (wheat bran carrier)

Method of Wang *et al.* (2019) was modified as the carrier, wheat bran, was autoclaved for 60 minutes at 120 degrees Celsius. To guarantee an even distribution of the combined carriers, each tested acetic acid solution was added separately to sterilise wheat bran at a rate of one to two and then completely mixed. Disinfected seeds (at rates of 5.0, 10.0, 15.0, 20.0, and 25.0 gm/Kg seeds) were added to the produced mixture. For every treatment, five duplicates were employed. The treated seeds were moved to a plate containing Czapek's medium (Difco, Detroit, MI) after 30 days, and they were then incubated for 7 days at 25ºC. It was determined what proportion of seeds had fungal development. Seeds

3. Results

3.1. Impact of AA vapors on storage fungal mycelial growth

Acetic acid vapours at 2.5, 5.0,7.5 and 9.0 µl/l (v/v) were tested against A. *flavus*, *A. niger*, and *F. verticillioides* mycelial growth. Results in Table (1) showed that all tested concentrations of of AA suppressed the mycelial growth of the all tested fungi. At 7.5 µl/l, AA vapour suppressed the *A. flavus* and *F. verticillioides*, while 9.0 µl/l inhibited *A. niger*. AA at 5.0 µl/l significantly decreased mycelial growth. Other concentrations produced a moderate effect.

Table 1: Impact of AA vapours on mycelial growth of associated fungi with some medicinal and aromatic seeds.

AA (µl/l)	Storage fungi					
	Aspergillus niger		*Aspergillus flavus*		*Fusarium verticillioides*	
	Linear growth	Reduction %	Linear growth	Reduction %	Linear growth	Reduction %
2.5	34.0 b	62.2	22.4 b	75.1	24.0 b	73.3
5.0	22.0 c	75.6	12.5 c	86.1	14.2 c	84.2
7.5	6.5 d	92.8	0.0 d	100.0	0.0 d	100.0
9.0	0.0 d	100.0	0.0 d	100.0	0.0 d	100.0
0.0	90.0 a	0.0	90.0 a	00.0	90.0 a	00.0

Figures with the same letter are not significantly different (P= 0.05)

3.2. Impact of AA vapors on storage fungal spore germination

Acetic acid vapours at 2.5, 5.0,7.5 and 9.0 µl/l (v/v) were tested against spore germination of A. *flavus*, *A. niger*, and *F. verticillioides.* Results in Table (1) showed that all tested concentrations of of AA suppressed spore germination of the tested fungi. At 7.5 µl/l, AA vapour suppressed the spore germination *A. flavus* and *F. verticillioides*, while 9.0 µl/l inhibited spore germination of *A. niger*. AA at 5.0 µl/l significantly decreased spore germination. Other concentrations produced a moderate effect.

Table 2: Impact of AA vapours on spore germination of storage fungi

AA (µl/l)	Storage fungi					
	Aspergillus niger		*Aspergillus flavus*		*Fusarium verticillioides*	
	Spore germination	Reduction %	Spore germination	Reduction %	Spore germination	Reduction %
2.5	22.4 b	76.5	18.0 b	81.3	21.4 b	77.3
5.0	14.5 c	84.8	10.2 c	89.4	15.3 c	83.8
7.5	5.0 d	94.8	0.0 d	100.0	0.0 d	100.0
9.0	0.0 d	100.0	0.0 d	100.0	0.0 d	100.0
0.0	95.2 a	00.0	96.5 a	00.0	94.2 a	00.0

Figures with the same letter are not significantly different (P=0.05)

3.3. Impact of AA solutions on mycelial growth and spore germination of storage fungi.

AA at 0.25, 0.50, 0.75 and 1.0 ml / L were tested against mycelial growth and spore germination of tested fungi. Results in Table (3) showed that all tried concentrations of of AA suppressed mycelial growth and spore germination of tested fungi. AA solution at 0.75/L completely suppressed the mycelial growth and spore germination of *A. flavus* and *F. verticillioides*, while at 1.0 ml/L inhibited mycelial growth and spore germination of *A. niger*. Other concentrations produced a moderate effect

Table 3: Impact of AA solutions on linear growth and spore germination of tested fungi

AA (ml/L)	*Aspergillus niger*		*Aspergillus flavus*		*Fusarium verticillioides*	
	Linear growth	Spore germinations	Linear growth	Spore germinations	Linear growth	Spore germinations
0.25	55.0b	51.0b	42.0b	45.0b	42.0b	44.0b
0.50	22.0c	18.0c	15.0c	18.0c	14.0c	15.0c
0.75	14.0d	12.0d	00.0d	00.0d	00.0d	00.0d
1.0	00.0e	00.0e	00.0d	00.0d	00.0d	00.0d
0.0	90.0 a	94.0a	90.0 a	95.0a	90.0 a	93.0

Figures with the same letter are not significantly different (P= 0.05)

3.4. Application methods

Two application methods *i.e.* Volatile assay (AA vapor) and Carrier contact assay(wheat bran carrier) were tested with the acetic acid at different concentrations to suppress fungal infection of some medicinal and aromatic seeds.

3.5. Volatile contact assay (vapour)

AA vapours at 0.050, 0.100, 0.150, 0.200 and 0.250 ml/l for 60 minutes in fumigation in especial chamber were tested against natural infection and germination of some medicinal and aromatic seeds.

3.6. Impact on natural infection

Results in Table (4 and Fig1.) all tried concentrations of AA significantly decreased the natural infection of tested seeds. Complete suppression of natural infection was achieved with AA at 250 ml /L. Followed by AA at 200 ml/L which reduced the natural infection by 77.0,80.0 and 79.0% for cumin, anis and caraway seeds respectively. the concentrations had moderate effect.

Table 4: Impact of acetic acid treatment applied as volatile assay on natural infection of some medicinal and aromatic seeds

AA (ml/l)	% Fungal natural infection					
	Cumin		Anise		Caraway	
	Infection %	Efficacy %	Infection %	Efficacy %	Infection %	Efficacy %
0.050	82.0 b	18.0	75.0 b	25.0	58.0 b	42.0
0.100	73.0 c	27.0	62.0 c	38.0	42.0 c	58.0
0.150	55.0 d	45.0	46.0 d	64.0	35.0 d	65.0
0.200	23.0 e	77.0	20.0 e	80.0	21.0 e	79.0
0.250	0.00 f	100.0	0.00 f	100.0	0.00 f	100.0
Control	100.0a	0.0	100.0 a	0.0	100.0 a	0.0

Figures with the same letter are not significantly different (P=0.05).

3.7. Impact on germination seeds

In Table (5) results show that all concentrations of AA decreased the seed germination. Complete suppression of germination was achieved with AA at 250 ml /L. AA at 200 ml/L recoded 34.0, 20.0 and 18.0 % as germination percent for cumin, anis and caraway seeds respectively. Othe concentrations had moderate effect

Table 5: Impact of acetic acid treatment applied as volatile assay on germination percent of some medicinal and aromatic seeds

AA (ml/l)	Seed germination %		
	Cumin	Anise	Caraway
0.050	75.0b	66.0a	67.0b
0.100	62.0c	44.0b	46.0c
0.150	51.0d	38.0c	40.0d
0.200	34.0e	20.0d	18.0e
0.250	00.0f	00.0e	00.0f
Control	100.0a	100.0 a	100.0 a

Figures with the same letter are not significantly different (P=0.05).

3.8. Carrier contact assay

Acetic acid solution was mixed with wheat bran and added to seeds at rate of 5.0,10.0,15.0 20.0 and 25.0 gm/Kg seeds were applied against natural infection and germination of seeds.

3.9. Impact on natural infection

Results in Table (6) all tested concentrations of AA significantly decreased the natural infection of tested seeds. Complete suppression of natural infection was obtained with AA at 25g/kg seeds. Followed by AA at 20 g/kg seeds ml/L which reduced the natural infection by 75.0,88.0 and 90.0% for cumin, anise and caraway seeds respectively. Othe concentrations had moderate effect.

Table 6: Impact of acetic acid treatment applied as Carrier contact assayon natural infection of some medicinal and aromatic seeds

AA Carrier (g/kg seeds)	% Fungal natural infection					
	Cumin		Anise		Caraway	
	Infection %	Efficacy %	Infection %	Efficacy %	Infection %	Efficacy %
5.0	75.0 b	25.0	65.0 b	35.0	60.0 b	40.0
10.0	52.0 c	48.0	43.0.0 c	57.0	50.0 c	50.0
15.0	48.0d	52.0	22.0 d	78.0	25.0 d	75.0
20.0	25.0	75.0	12.0 e	88.0	10.0	90.0
25.0	0.00 f	100.0	0.00 f	100.0	0.00 e	100.0
Control	100.0a	0.0	100.0 a	0.0	100.0 a	0.0

3.10. Impact on germination seeds

Results in Table (7) show that all tried concentrations of AA decreased the seed germination. Complete suppression of germination was achieved with AA at 25 g/kg seeds. AA at 20g/kg seeds recoded 22.0, 12.0 and 11.0 % as germination percent for cumin, anis and caraway seeds respectively. Othe concentrations had moderate effect

Table 7: Impact of acetic acid treatment applied as Carrier contact assay on germination percent of some medicinal and aromatic seeds.

AA Carrier (g/kg seeds)	Seed germination %		
	Cumin	Anise	Caraway
5.0	65.0b	59.0b	61.0b
10.0	44.0c	42.0c	45.0c
15.0	31.0d	24.0d	26.0d
20.0	22.0e	12.0de	11.0e
25.0	00.0f	00.0f	00.0f
Control	100.0a	100.0a	100.0a

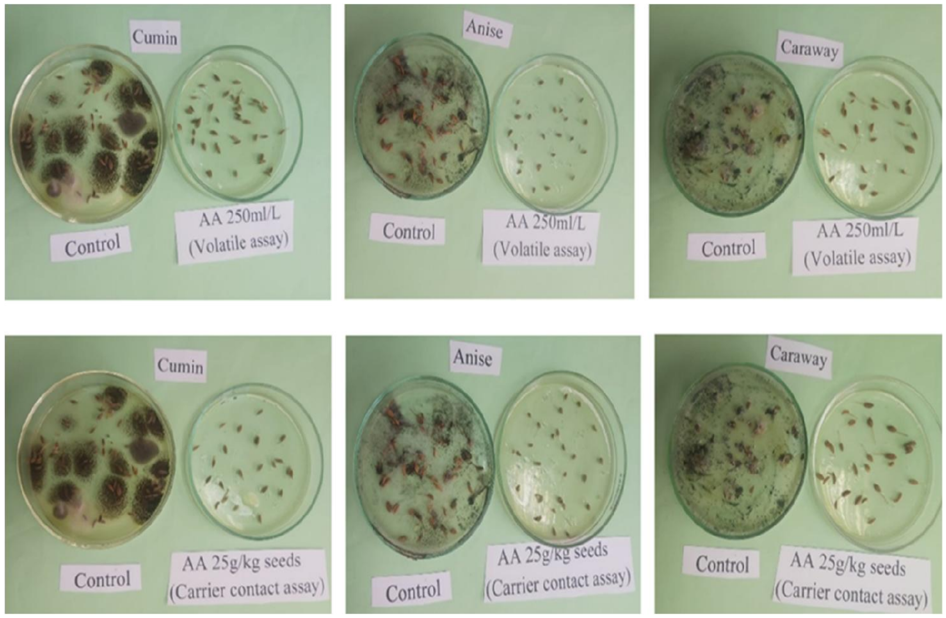

Fig. 1: Impact of acetic acid treatment applied as Volatile or Carrier contact assay on natural infection of some medicinal and aromatic seeds.

4. Discussion

The most significant medicinal and aromatic plants in Egypt and the world are fennel (*Foeniculum vulgare*), caraway (*Carum carvi*), anise (*Pimpinella anisum*), cumin (*Cuminum cyminum*), and coriander (*Coriandrum sativum*). Aspergillus species, Penicillium species, Rhizopus species, and Fusarium species are among the many fungus that attack and harm them after harvest and while they are being stored (Moharram *et al.,* 1989 and Regina and Roman 1992).

Acetic acid fumigation was effective against a wide rang of postharvest fungi (Sholberg *et al* ., 1998; Morsy *et al* ., 1999; Al-Ansary-Noran 2022 ; 2023 and Saied-Nehal, (2024) . Results of present study indicated at 7.5 µl/l, AA vapor suppressed the linear growth and spore germination of *A. flavus* and *F. verticillioides*, while 9.0 µl/l inhibited *A. niger*. Acetic acid solution at 0.75/L completely suppressed the linear growth and spore germination of *A. flavus* and *F. verticillioides*, while at 1.0 ml/L inhibited linear growth and spore germination of *A. niger*. Two application methods *i.e.* Volatile assay (AA vapor) and Carrier contact assay(wheat bran carrier) were tested with the acetic acid at different concentrations to suppress fungal infection. As for volatile assay results showed that complete suppression of natural infection was obtained with AA at 250 ml /L. Complete suppression of germination was achieved with AA at 250 ml /L. As for Carrier contact assay complete suppression of natural infection was obtained with AA at 25g/kg seeds. Complete suppression of germination was obtained with AA at 25 g/kg seeds. In this respect, when inoculated with A. flavus, AA vapours inhibited the storage diseases of wheat, rice, corn and canola (Sholberg and Gaunce, 1996 a). AA vapours were more successful to control postharvest deterioration of several fruits (Sholberge *et al.,* 1996; Sholberg *et al.,* 1998; Morsy *et al.,* 1999, 2000). Acetic acid vapour has a stronger inhibitory effect on bacteria than pH or undissociated acetic acid because it can permeate the microbial cell and exert its poisonous effect (Banwart 1981). AA suppression of microorganisms appears to influence the cell membrane, interfering with metabolite transport and membrane potential (Sholberg *et al.,* 1988).

AA vapour at low dosages has several properties which make it better biocide: First, it eliminates fungal spores; second, it doesn't damage the fumigated fruit's surface; and third, it works well at low temperatures, therefore fruit kept in cold storage at 1oC can benefit from acetic acid treatment. Fourth, at the low quantities required to destroy fungus spores, it is not flammable (Sholberg and Gaunce, 1995). AA vapours has several advantages for managing postharvest illnesses. At the low concentrations needed to destroy fungal spores, this naturally occurring chemical, which is found throughout the biosphere, poses little to no risk. According to Scholberg *et al.,* (1998), it is also widely accepted as a safe substance in the US, has no onerous registration requirements, is reasonably priced, and harmful to products in storage rooms or containers without needing product handling. A novel approach to controlling storage infection in affordable cereal grains may be the safe commercial use of acetic acid vapours.

Acetic acid is a ubiquitous metabolic intermediate found in both plant and animal (Busta and Foegeding 1983). It was widely employed by food manufacturers as an antibacterial preservative or acid in a number of food products (Davidson and Juneja, 1990). Acetic acid vapours were particularly successful in eliminating postharvest fungus spores that cause fruit rot (Sholberg *et al.,* 1998). AA fumigation inhibited postharvest degradation in several fruits (Sholberg and Gaunce 1995; Sholberg and Gaunce, 1996b; Sholberg *et al.,* 1996; Sholberg *et al.,* 1998).

Morsy *et al.,* (1999) discovered that AA vapours inhibited mycelial growth and spore germination of *B.cinerea and R. stolonifer*, which cause soft and gray rots in strawberries, at concentrations of 8 and 10 µl/l, respectively. AA vapours inhibited the incidence of strawberry postharvest diseases. Applying AA vapours to artificially infected canola, corn, rice and wheat seeds with high moisture content effectively prevented infection (Sholberg and Gaunce, 1996a). Acetic acid vapour treatments for grain seeds have been developed (Sholberg *et al.,* 2006). In preliminary testing (Pouleur *et al.,* 2008), acetic acid vapours were found to diminish viable *F. graminearum* populations in wheat and barley seeds without impacting germination. Morsy *et al.,* (2000) found that all fungal spore germination and linear growth were completely inhibited by AA vapour at 8 l/l. Because of its well-known antifungal and antibacterial properties, acetic acid has been used to manage plant diseases, notably fungus found in seeds. Acetic acid seed treatment has been demonstrated to effectively decrease leaf stripe (Pyrenophora graminea) and common bunt (Tilletia tritici) in wheat (Borgen and Nielsen, 2001; Saidi *et al.,* 2001; Sholberg *et al.,* 2006). Dorna *et al.,* (2021) shown that adding acetic vinegar to carrot seedlings can effectively suppress Alternaria spp. without negatively impacting seed germination (Dorna *et al.,* 2018).

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