P-ISSN: 3009 – 7487
E-ISSN: 3009 – 788

JOURNAL OF PLANT AND FOOD SCIENCES

June 2024

Pathological Studies on Wilt and Root Rot of Cumin and Their Management in Egypt

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Received: 27 th February 2024; in revised form: 1st March 2024 / Accepted: 1st March 2024 / Published: 1st June 2024
DOI 10.21608/JPFS.2024.273196.1008

ABSTRACT

Cumin (*Cuminum cyminum* L.) plant is one of the most popular spices and from important medicinal and aromatic plants in Egypt. Pathogens can lead to significant reductions in cumin yield. Cumin is attacked by several fungi. *Macrophomina phaseolina*, *Fusarium* spp., *Pythium* sp. and *Rhizoctonia solani* were isolated from cumin plants infected with root rot and wilt. Symptoms of wilt caused by *F. oxysporum* appeared 90 days after planting. *Pythium* sp. filtrate treatment was generally the most effective on the lowest mean percentage of cumin seed germination *in vitro*, followed by *F. oxysporum* and *F. solain*. Also, filtrates of *F. oxysporum* and *Pythium* sp. were the most effective in increasing wilted seedlings percentage. Thyme essential oil and Occidor 50% SC gave the highest reductions in damping- off (pre-, post- emergence) and wilt under greenhouse conditions. Whereas, Occidor 50%SC, Rhizo-N and Thyme oil gave the highest decrease percentages of wilt under field conditions. Thyme oil was generally the best treatment in increasing plant height and number of branches/plant than the other treatments, followed by Rhizo - N in increasing number of umbels/plant and seed yield (kg/fed.) than the control.
Keywords: Thyme - Essential oil- *Fusarium oxysporum* - *M. phaseolina* - *R. solani*.

INTRODUCTION

Cumin (*Cuminum cyminum* L.), Family Apiaceae, is one of the most popular spices and from important medicinal and aromatic plants in Egypt. In traditional medicine, cumin is used as a carminative for colic, diarrhea, and stomach problems. Cumin fruits, or seeds, are used as a spice to add taste to pickles, soups, and baked goods. Cumin aldehyde is the main component of the essential oil found in cumin fruits, which makes up 2-4 percent (Duke, 2002). During the 2010–2011 and 2012 growing seasons, the estimated cultivated area of cumin plants in Egypt was 5448, 3489, and 1941 feddan (Hassan *et al.*, 2014). The wilting of plants in their later stages of life, which has an impact on the quantity of seed yield, could be the cause of the previous years drop in the cultivated area. Cumin has been attacked by a number of different pathogens and has been severely impacted by wilt disease, which was caused by the soil-borne fungus *Fusarium oxysporum* f. sp. *cumini*. The damaging disease known as Fusarium wilt is also responsible for decreasing cumin yield (Arafa, 1985; Hilal *et al.,* 1993; Dange, 1995 and Khare *et al.*, 2014). Every stage of crop growth is affected by the disease that causes it. Plants that have the infection droop their leaves. When the roots are split open, the vascular region shows browning; appropriate blooming and fruiting do not occur when the wilting occurs during flowering. The pathogen is both soil- and seed-borne, occurring internally (Khare *et al.*, 2014). *Fusarium equiseti*, *F. dimerum*, *F. monileforme*, *F.*

solani, F. oxysporum and *F. lateritium* are the six species that cause root rot in cumin. *F. oxysporum, F. solani and R. solani* fungi belong to Deuteromycetes, have all been linked to root rot in China (Shujuan *et al.,* 2012). Most of these diseases are prevalent year after year. Inappropriate agricultural methods or insufficient resistance to various diseases could be the cause of this. Furthermore, it has been discovered that Fusarium wilt management in cumin can be effectively achieved by seed treatments containing essential oils and antagonists such *Trichoderma harzianum* and *Bacillus subtilis* (Tawfik and Allam, 2004). Additionally, Hashem *et al.* (2010) investigated the efficacy of a few essential oils in the management of cumin root rot, and the results indicated that the essential oils derived from cumin, basil, and geranium were the most successful in halting the illness. Because of their capacity to suppress phytopathogens and boost plant development promotion, *Trichoderma* spp. and *Bacillus* spp. are currently the most widely used as biocides agents against plant diseases (Kumar *et al.,* 2012 and Avşar *et al.,* 2017). In addition, organic acids are being investigated since traditional fungicides might leave behind toxic residues that could pose major issues for the environment and human health. Several researchers have reported using organic acids (antioxidants) to reduce fungal illnesses (Prusky *et al.,* 1995, Khan *et al.,* 2001 and Zaky and Mohamed, 2009). The aim of this research is to examine the prevalence and range of cumin root-rot and wilt diseases, as well as to identify the pathogens responsible for them. Create safe and effective control measures for these diseases as well. As a result, the current study broadens to assess several alternative fungicides in Middle Egypt in relation to a suggested fungicide alternatives and their impacts on plant growth metrics and wilt disease.

MATERIALS AND METHODS

Isolation and identification of the associated fungi:

Percentages of naturally diseased cumin plants showing symptoms of wilt and root rot were recorded in Qalubia and Minia governorates during 2018/2019 seasons. Percentages of infection, based on visual foliage symptoms were calculated. These symptoms were wilt, yellowing, dried shoots and stunting.

Sixty-day-old infected plants were removed from the field and brought into the lab. The roots that were affected by the disease were rinsed with tap water on many occasions, then sliced into little pieces and placed in a Petri dish. Finally, the surface of the roots was sterilized by immersing them in 2% sodium hypochlorite for one minute. Following that, they were rinsed once more with sterile water and then dried after being folded between two layers of sterile filter paper. The next step was to place the surface-sterilized pieces on a medium consisting of potato dextrose agar (PDA) inside of Petri dishes. Incubation of the plates was place for a duration of seven days at a temperature of 25 ± 2 degrees Celsius. Using single-spore or hyphae procedures, the developing fungi were purified (Brown, 1924 and Hansen, 1926). According to the descriptions given by Booth (1971), Domsch *et al.* (1980), and Neternick and Wandler (1981), the fungi were identified based on their morphological characters and were identified. Pure cultures were kept on potato dextrose agar slants at low temperature (5 °C) for further studies.

Pathogenicity test:

All of the isolated soil fungi, *Rhizoctonia solani*, *Pythium* sp., *Macrophomina phaseolina*, *Fusarium oxysporum* and *F. solani* that produce signs of wilt or root rot underwent a pathogenicity test. After one week of sterilization with a 5% formalin solution, the soil (one sand, one peatmoss, one clay w, w, w) was allowed to dry for two weeks before to usage. On autoclaved sorghum grains medium (100 grams of maize and 100 milliliters of water), test fungi were cultivated for 20 days at a temperature of 27 degrees Celsius. The previously isolated fungus was introduced into the soil at a rate of 1% by weight, thoroughly mixed with the soil in plastic pots with a diameter of 20 centimeters, and watered one week before to planting in order to encourage the colonization of the soil by the fungi. Cumin seeds were surface sterilized for three minutes using 0.1% v/v Clorox, followed by a rinse in sterilized distilled water and a drying period. Twenty seeds were placed in each pot. There were three copies of every treatment. The percentage of pre-, post-emergence damping-off and wilt occurred 25, 45, and 90 days after seeding, which was used to document the disease incidence. According to Waller *et al.* (2002), the percentage of plants that suffered from root rot and wilt was calculated as the disease percentage.

$$\text{Disease incidence \%} = \frac{\text{Number of diseased plants}}{\text{Total number of planted seeds}} \times 100$$

Re-isolated fungi from diseased plants were compared to the original isolates.

Laboratory studies:
Impact of fungal filtrates on:
Seed germination:

For the purpose of cultivating pathogenic fungus, specifically *R. solani, Pythium sp., M. phaseolina, F. oxysporum,* and *F. solani*, the liquid medium developed by Czapek was utilized. In a conical flask (250 ml) that contained 100 ml of media, one disc with a diameter of five millimeters was used to inoculate a culture that had been developing actively for ten days. There were three flasks used for each fungus, and they were incubated at a temperature of 25 degrees Celsius for a period of fifteen days. As a control, we utilized Czapek's medium that had been uninoculated. After the cultures were filtered through Whatman's No. 1 filter paper, they were sterilized with a Syringe Filter with a pore size of 0.45 m/µ. Five concentrations of each culture filtrate were prepared at the rates of 0.0,25,50,75 and 100 % using deionized water.

Cumin seeds were surface sterilized with clorox as fore-mentioned. Ten seeds were placed on sterilized filter paper per a dish (9 mm diam.), then 5 ml/dish from sterilized distilled water and/or sterilized fungal filtrate were added. After 7 days, the dishes were rewatered by 3 ml/dish of the fungal filtrate and/or distilled water to keep the humidity at suitable level. Three dishes were used for each treatment and incubated for 10 days at 25 ˚C. Percentages of the germinated seeds in each treatment were calculated.

Percentages of wilted seedlings:

Glass vials provided with equal amounts of the previously prepared sterilized fungal filtrates were used in this trial according to Nada (1997). Healthy seedling (30 – days – old) of cumin were planted in vials, contained 0.0,25,50,75 and 100% filtrates, under sanitation conditions. Three vials each treatment was planted at the rate of 4 seedlings/vial. Percentage of wilted seedlings were also recorded 72 hrs after planting.

Greenhouse experiments:

Twenty cm plastic pots were used for planting in the greenhouse experiment, and the mixture of clay soil, peatmoss and sand (1: 1: 1 w: w: w) had been formalin sterilized. Essential oil emulsions, peppermint and thyme were used at 6 ml/L (Ali *et al.*,2023), the bioagents: Plant-Guard and Rhizo-N were used at 5 ml/L, the chemical elicitor: ascorbic acid was used at 0.5 g/L water (Halawa *et al.*, 2018), also, fungicide of Occidor 50%SC (2 g/L water) were used throughout these experiments compared to control without treatment for each and every treatment, a set consisted of three replicates of the experiment. Following the processes described above, cumin seeds were soaked for thirty minutes and then air dried at room temperature for one hour. This was done after they had been repeatedly cleansed with sterile water and soaked for thirty minutes. Each treatment consisted of planting sixty cumin seeds in soil that was infested with *R. solani*, *M. phaseolina*, and *F. oxysporum* (each on its own). Twenty seeds were placed in each respective pot. The percentages of damping-off and wilt that occurred before, after, and after the emergence of plants were determined for those plants that survived 15, 30, 60, and 60 days after the date of planting, respectively.

Field experiments:

Field tests were carried out in Minia Governorate, during two successive seasons (2019/2020 and 2020/2021) to evaluate the effect of each fungicide-alternative material, *i.e.* Essential oil emulsions: peppermint and thyme were used at 6 ml/L (Hassanin *et al.*, 2017), the bioagents: Plant-Guard and Rhizo-N were used at 5 ml/L, the organic acid: ascorbic acid was used at 0.5 g/L water, also, fungicide of Occidor 50%SC (2 g/L water) were used throughout these experiments compared to control without treatment. After several sterilized water washes, cumin seeds were soaked for thirty minutes in previously treatments and air dried at room temperature for one hour before sowing. 3 replicates of each treatment were used in the split plot design experiment setup. The soil drench treatment was applied to the plots. Silty clay is the classification given to the trial site's soil. Plots were made and the fields prepped. Plot dimensions were 4.2 m2 (2.8 m x 1.5 m). Four rows of 70 cm in width and 2.8 meters in length made up each plot. Five seeds per hill were planted at a distance of 25 cm between cumin seeds. In a naturally cumin wilt-infested field, seeds were sown on November 1st of both seasons. Using ammonium sulphate (20.5% N), the appropriate amount of nitrogen was supplied at a rate of 250 kg/fed. Before seeding, 200 kg of phosphorus per feed were added to the soil and combined with calcium super phosphate (15.5% P2O5 P). Utilizing potassium sulfate (48% K2O), 50 kg of potassium was given. Ninety days after seeding, the incidence of cumin wilt was computed using the following formula:

$$(\%)\ \text{wilt} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Also, growth parameters were recorded as plant height (in centimeters), number of branches per plant, and number of umbels per plant were recorded in both seasons. Each plot's seed yield (kg) was noted during harvest and translated to kg/feddan.

Statistical analysis:

Using a total randomized design with three replicates per treatment, this study was designed as a factorial experiment (Snedecor and Cochran, 1989). Based on the Least Significant Difference (L.S.D) test at 0.05, this statistical analysis was conducted using MSTAT-C version (4) statistical package.

Table (1): Fungicide; trade names and formulations, common name, chemical composition and manufactures.

Trade name & Formulation	Common name	Chemical composition	Manufacture
Occidor 50% SC	**Carbendazim**	**Methyl 2-benzimidazole carbamate**	**Agriphar S.A., Belgium.**

Table (2): Biocides; commercial name, formulation, composition and manufactures.

Commercial name	Formulation	Composition	Manufacture
Plant Guard	Solution	The fungus: *Trichoderma harzianum;* 30×10^6cfu*/ml	El – Nasr Co. for Fertilization& Biocides, Egypt
Rhizo - N	Powder	The bacterium: *Bacillus subtilis;* 30×10^6cfu*/ml	El – Nasr Co. for Fertilization & Bbiocides, Egypt

*cfu = colony forming units.

RESULTS AND DISCUSSION

Isolation and identification of pathogens:

Disease symptoms of wilt and root rot in the field were stunting, yellowing, dried shoots, wilt and root rot (Fig.1). Disease survey was carried out in Minia and Qalubyia governorates, during 2018/2019 growing season in order to determine mean percentages of infection in cumin plantations and to collect diseased samples for isolation trials. Data presented in Table (3) show that mean percentage of infection was 15.7%. The highest percentage of infection (17.9%) was recorded in Minia governorate, whereas the lowest one was recorded in Qalubyia (13.5%). The observed increase in disease incidence in these governorates can be attributed to several factors. Firstly, the practice of planting crops in the same soil areas year after year, without implementing appropriate crop rotation, has been identified as a contributing factor. Secondly, the absence of high yielding and disease-resistant varieties has been identified as a contributing factor. Thirdly, there has been a lack of advancements in crop cultivation technology and its transfer to farmers. Lastly, there is a lack of knowledge regarding the current state of cultivation and future strategies for disease management.

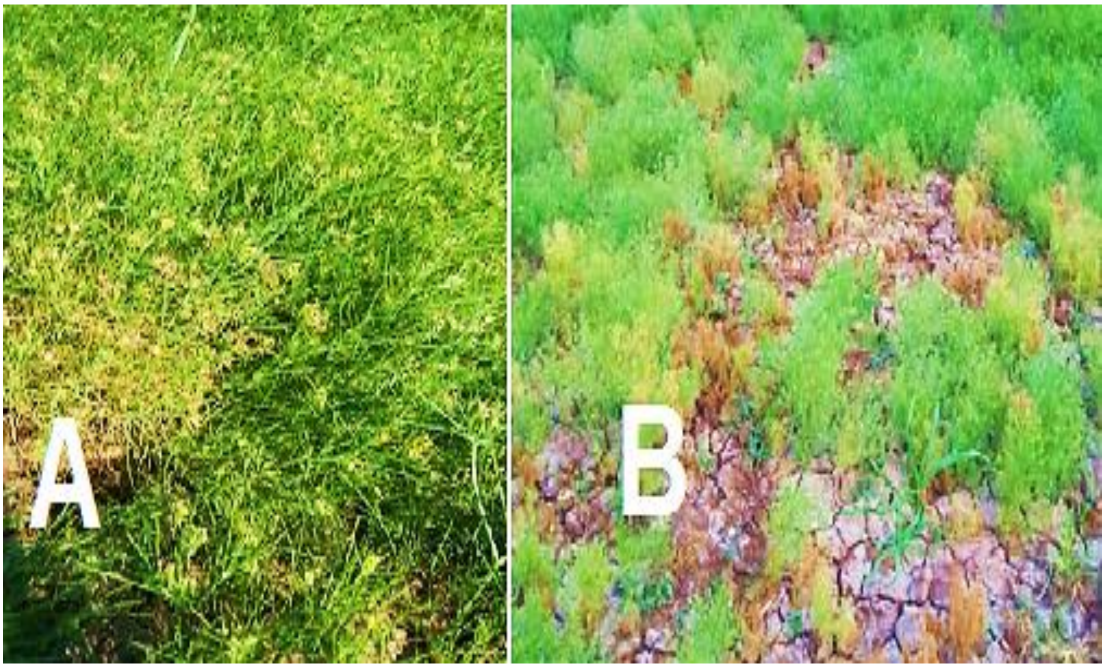

Fig. 1. Cumin plants naturally develop symptoms of wilting and root rot (A) (uninfected plant), B (infected plant).

Table (3): Percentages of natural infection on cumin plants grown in two governorates during 2018/ 2019.

Governorate	% of infection during season of: 2018/2019	Symptom
Minia	17.9	Yellowing, wilt, root rot, stunting and dryness.
Qalubia	13.5	
Mean	15.7	

Infected samples of cumin plants included fungi that belonged to four different fungal genera: Macrophomina, Fusarium, Pythium, and Rhizoctonia. During the 2018–2019 growing season, samples exhibiting signs of wilt and/or root rot were gathered from several sites within the governorates of Qalubyia and Minia. The isolated fungi were identified as *R. solani* Kuhn, *M. phaseolina* (Tassi) Goid., *F. solani* (Mart.) Appel & Wollenw and *F. oxysporum* Schlecht. Among the isolated fungus, *F. oxysporum* exhibited the greatest mean frequency (35.66%), followed by *R. solani* (32.66%), *M. phaseolina* (14.49%), *F. solani* (11.99%), and *Pythium* sp. (5.01%), according to Table 4 results. The sole isolate found on wilted plants was *F. oxysporum*. However, the other fungi that were separated from the cumin plants had rotted roots. In the two governorates, *F. oxysporum* was the most frequent isolated fungus in the two governorates followed by *R. solani*. These results are consistent with those of Hilal *et al.* (1993) and Abdallah *et al.* (2019), who investigated the fungal pathogens that cause soilborne cumin illnesses in Egypt.

Table (4): Frequency percentages of the isolated fungi from diseased cumin plants collected from two governorates during 2018/2019 season.

Isolated fungi	**%Frequency in governorates of:**			**Symptoms**
	Minia	Qalubyia	Mean	
Fusarium oxysporum	41.07	30.65	35.86	Root rot & Wilt
F. solani	14.29	9.68	11.99	Root rot
Macrophomina phaseolina	16.07	12.90	14.49	Root rot
***Pythium* sp.**	3.57	6.45	5.01	Root rot
Rhizoctonia solani	25.00	40.32	32.66	Root rot
Total	100	100	100	-

Pathogenicity test:

It was determined that every investigated fungal species (Table 5) and (Fig. 2) was harmful to cumin plants, exhibiting varying proportions of damping-off (pre- and post-emergence). *M. phaseolina* isolate No. 2 was responsible for the largest proportion (38.33%) of pre-emergence damping-off (2). In the meanwhile, isolates No. 1 and 2 of *R. solani*, No. 1 and 2 of *F. oxysporum*, and No. 2 of *M. phaseolina* showed the greatest percentages of post-emergence damping-off, at 33.33, 26.67, and 26.67%, respectively. However, ninety days after planting, *F. oxysporum* caused wilt symptoms started to show. In developing cumin plants, *F. oxysporum* (2) isolated from Qalubyia governorate showed the greatest percentage of cumin wilt (25.00%). Whereas, *M. phaseolina* (2) and *R. solani* (2) recorded the lowest percentages of survivals which recorded (35.00% & 38.34%) respectively. These results are somewhat consistent with those reported by Hilal *et al*. (1993) and Abdallah *et al.* (2019).

Table 5: The percentages of wilt infection and pre- and post-emergence damping-off that resulted from the fungi under test happened 25, 45, and 90 days after planting, respectively.

Fungi	% Damping-off		% Wilt	%Survivals
	Pre-emergence	Post-emergence		
Fusarium oxysporum (1)	8.33	26.67	23.33	41.67
F. oxysporum (2)	6.67	21.67	25.00	46.66
F. solani (1)	13.33	11.67	0.00	75.00
F. solani (2)	20.00	16.67	0.00	63.33
Macrophomina phaseolina (1)	31.67	25.00	0.00	43.33
M. phaseolina (2)	38.33	26.67	0.00	35.00
Pythium sp. *(1)*	16.67	31.67	0.00	51.66
Pythium sp. *(2)*	15.00	28.33	0.00	56.67
Rhizoctonia solani (1)	26.67	33.33	0.00	40.00
R. solani (2)	28.33	33.33	0.00	38.34
Control (without fungus)	0.00	0.00	0.00	100.00
L.S.D. at 5%	2.31	1.75	-	-

(1) Minia governorate isolate.
(2) Qalubyia governorate isolate.

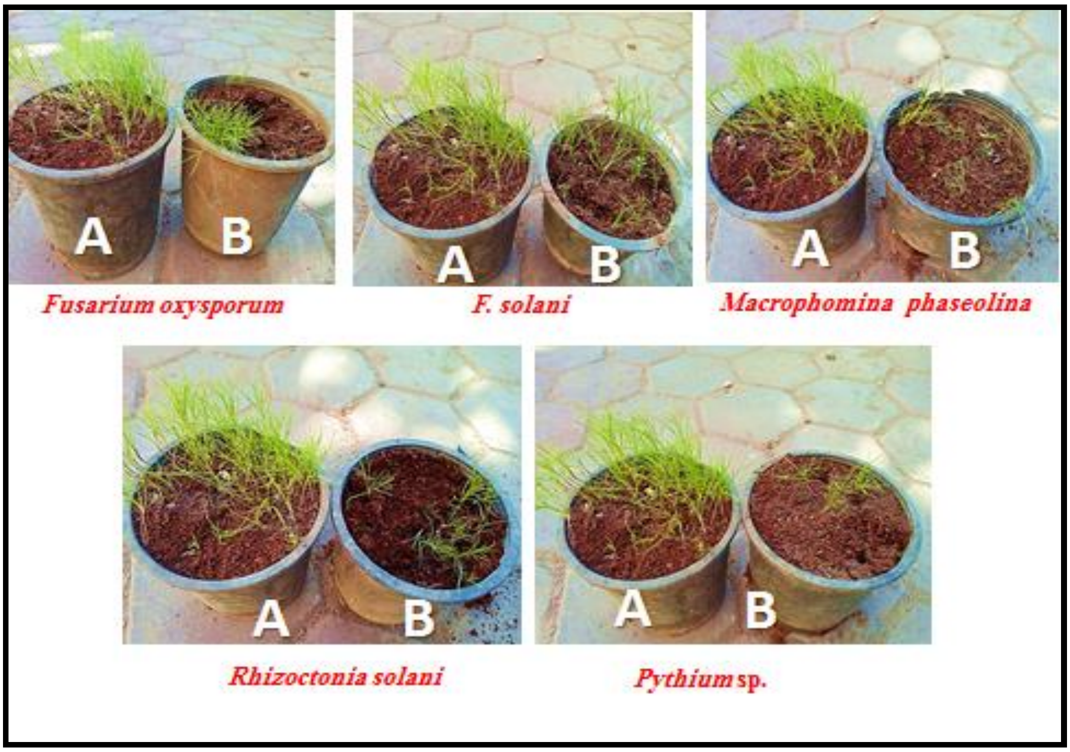

Fig. 2: In comparison to healthy plants (A), cumin plants grown in soil infested with fungi demonstrate indications of wilt and root rot diseases (B).

Laboratory experiments.
Effect of fungal filtrates on:
Seed germination:

The Impact of fungal filtrates of five fungi pathogenic to cumin plants used with four cocentrations, *i.e.* 25 %, 50 %, 75 % and 100 %, on percentages of cumin seed germination was determined (Table,6). All concentrations of the fungal filtrates significantly reduced the percentages of seed germination compared with the control treatment (water). In this respect, *Pythium* sp. filtrate was generally the most effective treatment since it resulted in the lowest mean percentage of seed germination (30.7 %) followed by *F. oxysporum* (34.7 %) and *F. solain* (37.3 %). In contrast, *R. solani* filtrate (40.7 %) was the least efficient one in decreasing the percentage of seed germination followed by that of *M. phaseolina* (38.7%). Moreover, percentages of seed germination significantly decreased by increasing concentrations of all fungal filtrates from 25 % to 100 % which entirely prevented seed germination. On the other hand, complete inhibition of seed germination was realized using 75 % concentration of fungal filtrates of *F. oxysporum*, *M. phaseolina* and *Pythium* sp. These results are in agreement with those obtained by Imarah (2000), Mahmoud (2004) and Hassanin (2007).

Table (6): Impact of five fungal filtrates on percentages of cumin seed germination, incubated at 25 °C for 10 days.

Fungi	% seed germination at Concentrations (%):					Mean
	0.0	25	50	75	100	
Fusarium oxysporum	100	56.7	23.3	0.0	0.0	34.7
F. solanin	100	43.3	30.0	16.7	0.0	37.3
Macrophomina phaseolina	100	53.3	33.3	0.0	0.0	38.7
Pythium sp.	100	36.7	20.0	0.0	0.0	30.7
Rhizoctonia solani	100	63.3	26.7	3.3	0.0	40.7
Mean	100	56.2	25.2	7.1	0.0	---
L.S.D.at 5 % for:	Fungi (F)= 2.1		Concentrations (C)= 1.8		(F) × (C)= 3.7	

Percentages of wilted seedlings:

Table (7) demonstrate that all fungal filtrates tested induced wilt symptoms of cumin seedlings after 72 hrs from treatment, since they increased percentages of wilted seedlings compared with their controls. A positive relationship was realized between percentages of wilted seedlings and concentrations of these fungal filtrates. In this respect, filtrates of *F. oxysporum (*41.7%) and *Pythium* sp. (30.3%) were, however, the most effective ones as they recorded the highest mean percentages of wilted seedlings. Moreover, the lowest cocentrations of these filtrates (25 conc.) recorded significant increases in wilted seedlings (%) in case of *F. oxysporum* (25.0%) and *Pythium* sp. (16.7 %), compared with the control ones (0.0%), whereas their crude filtrates (100 conc.) figured 100.00 % and 60.0 % wilted seedlings. In contrast, filtrates of *M. phaseolina* and *R. solani* were the least efficient treatments recording mean percentages of wilted seedlings by 10.0 % and 21.7 %, respectively. Whereas, the lowest concs. (25% & 50%) were completely noneffective in case of *M. phaseolina*, while, the lowest concs. (25%) was completely noneffective in case of *R.*

solani. These results are in harmony with those reported by El-Garhy (1994) found that the culture filtrates of *R. solani, F. oxysporum* and *M. phaseolina* caused necrotic spots in lentil leaf tissues as well as softening and browning of veins. Also, Hassanin (2007) found that the fungal filtrates of *F. oxysporum* and *Pythium* sp. were the most effective in increasing percentages of wilted marjoram seedlings.

Table (7): Impact of five fungal filtrates on percentages of wilted cumin seedlings after 72 hours of incubation.

Fungi	% Concentrations					Mean
	0.0	25	50	75	100	
Fusarium oxysporum	0.0	25.0	33.3	50.0	100.0	41.7
F. solani	0.0	8.3	16.7	33.3	58.3	23.3
Macrophomina phaseolina	0.0	0.00	0.00	16.7	33.3	10.0
Pythium sp.	0.0	16.7	33.3	41.7	60.0	30.3
Rhizoctonia solani	0.0	0.00	16.7	33.3	58.3	21.7
Mean	0.0	10.0	20.0	35.0	62.0	---
L.S.D.at 5 % for:	Fungi (F)= 7.8	Concentrations (C) = 5. 2		(F) × (C) = 11.4		

Greenhouse experiments:

The study investigated the effects of biocides (Plant-Guard and Rhizo-N), chemical elicitor (ascorbic acid), essential oils emulsions (peppermint and thyme), and fungicide (Occidor 50%SC) on pre- and post-emergence damping-off, wilt, and survival of plants in soil artificially infested with *R. solani, M. phaseolina* and *F. oxysporum.* The experiments were conducted after 15 to 60 days after planting. The findings displayed in Table 8 indicate that, under greenhouse circumstances, all treatments exhibited a significant reduction in the proportions of damping-off (both before and after emergence), wilt, and increasing plant survivals (%) when compared to the control group. The biggest reductions in percentages of pre- and post-emergence damping-off and wilt were observed with the application of Occidor 50% SC and thyme essential oil. In contrast, the treatment that exhibited the lowest success rate in terms of pre-emergence damping-off, specifically wilt, was Plant Guard biocide. Conversely, peppermint oil demonstrated the lowest success rate in terms of post-emergence damping-off percentages. The Thyme oil and Occidor 50% SC had the highest rates of survival, respectively. On contrast, the least successful treatment for improving plant survival rates was Plant Guard. Due to the antifungal abilities of these treatments, which may be totally or partially inhibit or postpone the processes of fungal infection and disease development, cumin seedlings may be protected against root rot and wilt pathogens following seed planting. However, the current favorable outcomes of the tested treatments against pathogenic fungus to cumin may be explained and backed by results of Hilal *et al.* (1993) and Abdallah *et al.* (2019). Also, the tested treatments might stimulate some defense mechanisms such as oxidative enzymes and by products in plants emerged from treated black cumin seeds.

Table (8): Impact of dipping cumin seeds in two essential oils before to planting with varying treatments on (%) damping-off (pre-, post-emergence) and wilt at 25, 45, and 90 days after planting, in a greenhouse conditions.

Treatments (A)	Fungi (B)	Damping-off (%) Pre-Emergence	Damping-off (%) Post-emergency	(%) Wilt	% Survival
Peppermint oil (4 ml/L)	*F. oxysporum*	8.3	3.3	0.0	88.4
	M. phaseolina	3.3	6.7	0.0	90.0
	R.solani	16.7	3.3	0.0	80.0
Mean		9.4	4.4	0.0	86.1
Thyme oil (4 ml/L)	*F. oxysporum*	3.3	0.0	0.0	96.7
	M. phaseolina	3.3	0.0	0.0	96.7
	R.solani	3.3	0.0	0.0	96.7
Mean		3.3	0.0	0.0	96.7
Plant Guard (5 ml/L)	*F. oxysporum*	6.7	6.7	6.7	79.9
	M. phaseolina	10.0	3.3	0.0	86.7
	R.solani	16.7	0.0	0.0	83.3
Mean		11.1	3.3	2.2	83.3
Rhizo - N (5 ml/L)	*F. oxysporum*	3.3	3.3	0.0	93.4
	M. phaseolina	3.3	3.3	0.0	93.4
	R.solani	15.0	0.0	0.0	85.0
Mean		7.2	2.2	0.0	90.6
Ascorbic acid (0.5 g/L)	*F. oxysporum*	6.7	6.7	3.3	83.3
	M. phaseolina	6.7	3.3	0.0	90.0
	R.solani	10.0	0.0	0.0	90.0
Mean		7.8	3.3	1.1	87.8
Occidor 50%SC (2 g/L)	*F. oxysporum*	3.3	0.0	3.3	93.4
	M. phaseolina	0.0	3.3	0.0	96.7
	R.solani	0.0	3.3	0.0	96.7
Mean		1.1	2.2	1.1	95.6
Control	*F. oxysporum*	10.0	16.7	26.7	46.6
	M. phaseolina	13.3	10.0	0.0	76.7
	R.solani	26.7	10.0	0.0	63.3
Mean		16.7	12.2	8.9	62.2
L.S.D. at 5%:		0.4	0.5	0.3	0.3
	Treatments (A)=	0.2	0.2	0.1	0.2
	Fungi (B)=	0.5	0.7	0.5	0.4
	(A)X (B)=				

Field experiments :

Impact of different control methods on:

Disease incidence (%):

According to data in Table 9, following ninety days of planting, the percentages of wilt incidence were significantly decreased by all evaluated treatments. Occidor 50%SC, Rhizo-N and Thyme oil gave the highest decrease percentages in both seasons, 2019/2020 and 2020/2021, respectively. On the other hand, Peppermint oil was the least effective treatment in 2019/2020 season. However, in the cases of Occidor 50%SC, Rhizo-N, and Thyme oil in both the 2019/2020 and 2020/2021 seasons, the highest survival rate of plants was recorded. Whereas, Peppermint oil was the least effective treatment in increasing survivals in 2019/2020 season. The positive efficiency of various control treatments such as essential oil emulsions, biocides, elicitors and fungicides, separately or together, against soilborne diseases (root rot and/or wilt) was previously confirmed on cumin (Hilal *et al*., 1993 and Abdallah *et al*., 2019) and chia (El-Kaed *et al*., 2021).

Table (9): Impact of treatments on wilt incidence (%) and survival (%) during seasons of 2019/2020 and 2020/2021.

Treatments	2019/2020 season		2020/2021 season	
	% Wilt incidence after 90 days	% Survival	% Wilt incidence after 90 days	% Survival
Peppermint oil (4 ml/L)	6.7	93.3	3.3	96.7
Thyme oil (4 ml/L)	0.0	100.0	0.0	100.0
Plant Guard (5 ml/L)	3.3	96.7	3.3	96.7
Rhizo - N (5 ml/L)	0.0	100.0	0.0	100.0
Ascorbic acid (0.5 g/L)	3.3	96.7	3.3	96.7
Occidor 50%SC (2g/L)	0.0	100.0	0.0	100.0
Control(without treatment)	13.3	86.7	10.0	90.0
L.S.D. at 5%	5.5	-	6.4	-

Plant growth parameters:

The collected results (Tables 10, 11, 12, 13, and 14) demonstrate that all treatments tested outperformed the control (no treatment) in terms of plant growth metrics, such as plant height, number of branches/plant, number of umbels / plant, and seed production (kg/fed.). Nonetheless, there were significant distinctions between these treatments and the controls. Increases in plant height ranged between (24.00 - 25.50cm) and (24.32 -26.66cm) in the two experimental seasons. While, they were ranged between (6.27 - 7.83) and (6.72 - 7.38) for number of branches/plant in (2019/2020 and 2020/2021 seasons), respectively. Also, the increases in number of umbels/plant ranged between (18.33 -22.00) and (18.88 - 22.22) for both seasons, whereas they were (426.30 - 481.90 kg/fed.) and (442.00 - 474.51 kg/fed.) in case of seed yield (kg/fed.) for 2019/2020 and 2020/2021, respectively. Thyme oil was generally the best dipping treatment in increasing plant height and number of branches/plant than the other treatments, followed by Rhizo-N in increasing number of umbels/plant and seed yield (kg/fed.) than the control. In contrast, peppermint oil and Plant Guard were the least effective treatments in both trial seasons. The biochemical changes in the stem base tissues may be responsible for the improvements in plant growth parameters after seed treatment. Protease activity, growth hormones, and phenol chemicals are all increased in this alteration. The studies by Hilal *et al.* (1993), Hassanin (2013), Abdallah *et al.* (2019), and El-Kaed *et al.* (2021) on a variety of crops grown in soil that was either naturally or intentionally infected provided similar findings.

Table (10): Impact of treatments on plant height (cm) of plants during 2019/2020 and 2020/2021 growing seasons.

Treatments	Plant height (cm)	
	First season (2019/2020)	Second season (2020/2021)
Peppermint oil (4 ml/L)	24.16	24.32
Thyme oil (4 ml/L)	25.50	26.66
Plant Guard (5 ml/L)	24.00	24.55
Rhizo - N (5 ml/L)	24.61	25.94
Ascorbic acid (0.5 g/L)	24.93	26.05
Occidor 50%SC (2 g/L)	24.36	25.36
Control(without treatment)	23.22	23.61
L.S.D. at 5%	0.71	0.73

Table (11): Impact of treatments on number of branches/plant of plants during 2019/2020 and 2020/2021 growing seasons.

Treatments	Number of branches/plant	
	First season (2019/2020)	Second season (2020/2021)
Peppermint oil (4 ml/L)	6.27	6.72
Thyme oil (4 ml/L)	7.83	7.38
Plant Guard (5 ml/L)	6.66	6.99
Rhizo - N (5 ml/L)	7.27	6.94
Ascorbic acid (0.5 g/L)	6.66	6.88
Occidor 50%SC (2 g/L)	7.05	7.27
Control(without treatment)	5.16	5.94
L.S.D. at 5%	0.34	0.48

Table (12): Impact of treatments on number of umbels/plant of cumin plants during 2019/2020 and 2020/2021 growing seasons.

Treatments	Number of umbels/plant	
	First season (2019/2020)	Second season (2020/2021)
Peppermint oil (4 ml/L)	19.94	18.88
Thyme oil (4 ml/L)	20.22	20.11
Plant Guard (5 ml/L)	18.33	18.99
Rhizo - N (5 ml/L)	22.00	22.22
Ascorbic acid (0.5 g/L)	19.63	19.44
Occidor 50%SC (2 g/L)	20.10	19.71
Control(without treatment)	17.66	18.38
L.S.D. at 5%	1.70	0.48

Table (13): Impact of treatments on seed yield (kg/fed.) of cumin plants during 2019/2020 and 2020/2021 growing seasons.

Treatments	Seed yield (kg/fed.)	
	First season (2019/2020)	Second season (2020/2021)
Peppermint oil (4 ml/L)	426.30	442.00
Thyme oil (4 ml/L)	478.80	469.60
Plant Guard (5 ml/L)	459.80	464.60
Rhizo - N (5 ml/L)	481.90	474.51
Ascorbic acid (0.5 g/L)	468.30	456.62
Occidor 50%SC (2 g/L)	464.20	452.93
Control(without treatment)	417.40	432.21
L.S.D. at 5%	7.80	6.44

Conclusion

This study evaluated the effectiveness of oil: Peppermint and Thyme, biocides: Plant Guard and Rhizo-N, organic acid: Ascorbic acid and fungicide: Occidor 50%SC for controlling of cumin root rot and wilt. According to the obtained results; Occidor 50%SC, Rhizo-N and Thyme oil gave the highest decrease percentages of wilt under field conditions. Thyme oil was generally the best treatment in increasing plant height and number of branches/plant than the other treatments, followed by Rhizo-N in increasing number of umbels/plant and seed yield (kg/fed.) than the control.

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