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Full Length Research Paper

Composition and *in vitro* antifungal activity of *Bunium persicum*, *Carum copticum* and *Cinnamomum zeylanicum* essential oils

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Essential oils of *Bunium persicum* (Parsi Zira), *Carum copticum* (Ajwain) and *Cinnamomum zeylanicum* (cinnamon) were tested *in vitro* as growth inhibitors against six forma special of *Fusarium oxysporum*. Minimum inhibitory concentration (MIC) and median effective concentrations (EC_{50}) values (µl/L) were also demonstrated. The antifungal activity of essential oils was assayed by poison food medium method (0, 100, 200, 300, 400, and 500 µl/L). Essential oils were extracted by means of hydro-distillation and afterwards, gas chromatography-mass spectrometry (GC-MS) analysis was performed to identify their components. The main constituents were cinnamaldehyd (77.51%), β-linalool (11.13%), α-cubebene (1.18%) and 1S, CIS-calamenene (1.06%) for *C. zeylanicum*, thymol (52.95%), γ-terpinene (13.53%), p-cymene (11.28%) in *C. copticum* and γ-terpinene (24.02%), cuminaldehyde (20.1%), para-cymene (13.09%), benzenemethanol alpha-propyl (13.01%), cyclopentane, 2-methyl-1-methylene-3-(1-methylethenyl) (3.57%) in *B. persicum*. All three essential oils exhibited antifungal effect on the studied fungi species; but essential oil of *C. zeylanicum* was more effective. The growth of *F. oxysporum f. sp. lycopersici, F. oxysporum f. sp. ciceri* and *F. oxysporum f. sp. melonis* was completely inhibited by essential oil of *C. zeylanicum* at 200 ppm concentrations.

Key words: Antifungal activity, essential oils, *Fusarium oxysporum*.

INTRODUCTION

Plant pathogens that include fungi, nematodes, bacteria and viruses can cause diseases or damages in plants (Montesinos, 2003). Among these, fungi are the main pathogen and cause many diseases in plants. Pathogenic fungi also cause yield losses in numerous economically important crops (Fletcher and Bender, 2006). The genus *Fusarium* is widely found in plant debris and crops (Marasas et al., 1984). Several species from this genus are economically relevant. Fungi can infect and cause tissue destruction on important crops such as corn, wheat and other small grains in the field. Additionally, they produce mycotoxins on crops in field and in storage grains (Dambolena and Zunino, 2010).

Fusarium oxysporum is a ubiquitous soil-borne fungus that includes pathogenic and non-pathogenic members. The pathogenic members are best-known for wilting diseases on many economically important crops (McClellan and Pryor, 1957). Synthetic fungicides are currently used as the primary means for plant diseases control. However, the alternative control methods are needed due to the negative public concerns about the use of synthetic chemicals, resistance of fungal pathogens to fungicides, and environmental risks. Therefore, biological control seems to be a good alternative for chemicals control (Mares et al., 2004). The

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Abbreviations: GC-MC, Gas chromatography-mass spectrometry; **MIC,** minimum inhibitory concentration; **PDA,** potato dextrose agar.

use of plant derived products as diseases control agents have been studied, since they tend to have low mammalian toxicity, less environmental effects and wide public acceptance (Lee et al., 2007). Particularly, essential oils were found to exert good antifungal activities both *in vitro* and *in vivo* conditions against a wide range of pathogens (Baruah et al., 1996; Caccioni et al., 1998; Reddy et al., 1998; Sharma and Verma, 2004). They may provide potential alternatives to control the agents that are currently used due to their bioactive chemicals content (Isman, 2000).

Parsi Zira (*Bunium persicum*) is a native plant of limited zones of the West Asia and it grows in northern areas of Khorasan, Kerman, and East of Zagros to Bandar Abbas and South of Alborz in Iran (Bonianpoor, 1995). Generally, Umbeliferae species including *B. persicum* have antimicrobial properties (Shetty et al., 1994). Sekine et al. (2007) studied antifungal activities of volatile compounds on 52 species against four phytopathogenic fungi and their results showed that *B. persicum* had the strongest antifungal activity.

The other studied species was Ajwain (*Carum copticum*) from Umbelliferae family. The mentioned plan is cultivated in black soils particularly along the riverbank throughout India, Iran, Egypt and Afghanistan. This plant grows in Sistan and Baluchestan, Azarbaijan, Esfahan, Khuzestan, Fars, Kerman and Khorasan provinces in Iran. Seeds of this plant are rich in thymol.

Cinnamon (*Cinnamomum zeylanicum*) is a plant of the Lauraceae family and native to Indonesia; but cultivated in Srilanka and India. The main chemical components of the essential oil, obtained from the leaves, are eugenol, eugenol acetate, cinnamic aldehyde and benzyl benzoate.

However, the aim of this study was to evaluate the efficacy of three natural essential oils in control of diseases caused by *F. oxysporum. f. sp. lycopersici, F. oxysporum f. sp. ciceri* and *F. oxysporum f. sp. melonis* at *in-vitro* condition.

MATERIALS AND METHODS

Extraction of essential oils

Seeds of *B. persicum* and *C. copticum*, and stem bark of *C. zeylanicum* were powdered using a blender. The essential oil was extracted for 3 h by hydrodistillation, using Clevenger-type apparatus. Extracted oils were dried by anhydrous sodium sulfate, poured in opaque vials and were stored at 4°C till gas chromatography-mass-spectrometry (GC-MS) analysis.

GC-MS analysis of essential oil

GC-MS analysis was done at 250°C on an Agilent 6890 gas chromatograph at 70 eV. The GC column was as follows: HP-5MS; the size of fused silica capillary was 0.25 × 3000 µm with film thickness of 0.25 µl. In addition, the GC-MS was operated under the following condition: the initial temperature was 50°C and was heated for 5 min, then it was heated up to 240°C at the rate of 3°C per min. Meanwhile, carrier gas (helium) flow was 0.8 ml/min.

Identification of compounds was done based on the following explanation: the retention indices were calculated for all volatile constituents using a homologous series of n-alkanes C_6 to C_{24}. Moreover, the method of mass spectra was used for the identification of individual compounds with those of similar compounds from a database (Wiely/NBS library) or with authentic compounds and it was confirmed by the comparison of their retention indices with authentic compounds or with those reported in the literature (Ozcan et al., 2006). For quantification purpose, relative area percentages obtained by flame ionization detector (FID), were used without using correction factors.

Bioassay of pathogens

Samples of infected chickpea, tomato and cantaloupe (Melon) with *Fusarium* wilt symptoms were collected from Kurdistan, Fars and Markazi provinces of Iran. Pathogens were cultured on potato dextrose agar (PDA) at 26 ± 2°C and were stored at 5 to 8°C. Isolates of *F. oxysporum* recovered from infected plants were tested for their pathogenicity on chickpea, tomato and cantaloupe plants. Seeds sown in sterilized soil were infested with the pathogens in 10 cm diameter pots at a rate of 10^6 cfu/g. Control pots were without any inoculation of pathogen. Pots watered daily and after five weeks treatments were indexed and wilted plants were recorded over time for disease occurrence and pathogen re-isolated from diseases plants.

In vitro antifungal efficacy measurements

The fungal toxicity of the essential oils was evaluated against pathogens by using poisonous media technique (Mishra and Dudey, 1994). Five concentrations (100, 200, 300, 400, and 500 ppm) were mixed with PDA media in 40°C. Requisite amounts of the essential oils were dissolved separately in 0.5 ml of 0.1% Tween-80 and then were mixed with PDA medium for even distribution of the oil in PDA media. For control sets, the requisite amount of sterilized water in place of the oil was added to the medium.

The PDA with added oils was then poured into 9 cm Petri dishes. For inoculation, mycelium was taken from the periphery of 7-day old stock cultures. Plugs of mycelium were removed with a 6 mm diameter cork borer, inverted, and where placed in the center of each Petri dish. Plates were sealed with parafilm to prevent realization of volatile compounds. Four replicate plates were sited up for each concentration, and were plates incubated in the dark at 26 ± 2°C. Fungi toxicity was expressed in terms of percentage of mycelia growth inhibition and was calculated (Pandey et al., 1982). The percentage of growth inhibition of mycelia was calculated by formula $I = [(d_c-d_t)/d_c \times 100]$, where I = percentage of growth inhibition, d_c = radial growth of pathogen in control, and d_t = radial growth of pathogen in treatment. For detection of fungistatic or fungicide effect in which oil was inhibited, fungal disc was re-inoculated onto the fresh PDA media and revival of fungal growth was recorded at 26 ± 2°C after 10 days. Then, median effective inhibitory concentration (EC_{50}) of essential oils was measured.

Data analysis

Statistical analysis of the obtained data were performed with MSTATC statistical software (Freed et al., 1991) using completely randomized design (CRD) with 4 replicates. Data were subjected to analysis of variance (ANOVA) and mean differences were established by Duncan's multiple range test ($P < 0.05$). Probit analysis was used to measure EC_{50} with POLO-PC software (2002).

Table 1. Components of *C. zeylanicum* essential oil identified by GC-MS analysis.

S/N	Retention time (min)	Compound	Percentage
1	15.18	Benzene, 1-methyl-4-(1-methylethyl)	0.18
2	24.98	Cinnamaldehyd	77.51
3	29.34	β-linalool	11.13
4	29.56	p-Cymen-3-ol	0.28
5	30.08	2-Propenal, 3-phenyl	0.24
6	32.17	α-Cubebene	1.18
7	35.04	Di hydrocoumarin	0.12
8	35.28	Trans-cinnamyl acetate	0.54
9	36.34	Naphthalene, 1, 2, 3, 4, 4a, 5, 6, 8a-octahydro-7-methyl-4-methylene-1-(1-methylethyl)-, (1.alpha.,4a.beta.,8a.alpha.)	0.21
10	37.08	Aromadendrene	0.11
11	37.34	α.-Muurolene	0.6
12	37.66	β-Bisabolene	0.07
13	37.87	α- amorphene	0.08
14	38.29	1S, CIS-Calamenene	1.06
15	38.93	Para methoxy cinnamic aldahyde	3.7
16	39.10	Calacorene	0.3
17	40.20	Caryophyllenyl alcohol	0.07
18	40.52	Spathulenol	0.05
19	41.45	3, 7-Cycloundecadien-1-ol, 1, 5, 5, 8-tetramethyl	0.09
20	41.61	Germacrene D	0.05
21	42.40	Naphthalene, 1, 2, 3, 4, 4a, 7-hexahydro-1, 6-dimethyl-4-(1-methylethyl)	0.25
22	42.96	t-Cadinol	0.56
23	43.11	Copaene	0.29
24	43.42	α-Cadinol	0.09
25	44.10	Naphthalene, 1, 6-dimethyl-4-(1-methylethyl)	0.13
26	44.25	Oxo-α-ylangene	0.21
27	44.55	α-Bisabolol	0.11
28	70.21	Bis (2-ethylhexyl) phthalate	0.78

RESULTS

Chemical analysis of essential oils by GC-MS allowed identification of cinnamaldehyd (77.51%), β-linalool (11.13%), α-cubebene (1.18%) and 1S, CIS-calamenene (1.06%) for *C. zeylanicum* (Table 1); thymol (52.95%), γ-terpinene (13.53%) and p-cymene (11.28%) for *C. copticum* (Table 2); and γ-terpinene (24.02%), cuminaldehyde (20.1%), para-Cymene (13.09%), benzene methanol, alpha-propyl (13.01%), cyclopentane, 2-methyl-1-methylene-3-(1-methylethenyl) (3.57%) for *B. persicum* (Table 3) as the main components.

Pathogenicity bioassay

Six isolates of pathogens were obtained from diseased potato, chickpea, and cantaloupe. These isolates belong to *F. oxysporum f. sp. lycopersici* (F27 and F37), *F. oxysporum f. sp. ciceris* (F3 and F6) and *F. oxysporum f. sp. melonis* (F12 and F22). *In-vitro* antifungal activities of oils showed that all studied essential oils had inhibitory effect on tested isolates. The essential oil obtained from the bark of *C. zeylanicum* showed the highest antifungal activity against all fungi tested. Mycelial growth of *F. oxysporum f. sp. cicer* (F3 and F6) and *F. oxysporum f. sp. lycopersici* (F27) were completely inhibited by essential oil of *C. zeylanicum* at a concentration of 100 ppm (Table 4), whereas meclial growth was inhibited completely in *F. oxysporum f. sp. melonis* (F12 and F22) and *F. oxysporum f. sp. lycopersici* (F37) at a concentration of 200 ppm.

The results of antifungal activity assays showed that *C. copticum* oil had inhibitory effects on fungi growth at a broad spectrum. All tested fungi species growth were reduced completely by 500 ppm, and in some cases, the

Table 2. Components of *C. copticum* essential oil identified by GC-MS analysis.

S/N	Retention time (min)	Compound	Percentage
1	10.38	α.-Thujene	0.29
2	10.67	α.-Pinene	0.26
3	12.79	2-β-Pinene	1.42
4	13.59	β-Myrcene	0.45
5	14.18	1-Phellandrene	0.29
6	14.81	α-Terpinene	0.27
7	15.55	p-Cymene	11.28
8	15.77	Benzene, 1-methyl-3-(1-methylethyl)	1.55
9	15.82	Benzene, 1-methyl-4-(1-methylethyl)	0.59
10	15.87	α-Limonene	1.55
11	15.91	1, 8-Cinessential oille	0.06
12	17.47	γ-Terpinene	13.53
13	17.70	Trans-sabinene hydrate	2.62
14	18.53	α-Terpinolene	0.08
15	19.05	Cis-sabinene hydrate	0.03
16	19.20	Linalool L	0.2
17	22.89	Terpinene-4-ol	0.2
18	25.58	α-Terpinessential oil	0.12
19	26.00	Cyclohexanone, 2-methyl-5-(1-methylethenyl)	0.22
20	26.43	Cyclohexanone, 2-methyl-5-(1-methylethenyl)- trans	0.22
21	27.02	Cymene	0.04
22	27.59	Propanal, 2-methyl-3-phenyl	0.12
23	28.04	Trans-anethole	1.11
24	29.19	Thymol	52.95
25	30.18	Carvacrol	0.08
26	31.24	Chrysanthenone	0.06
27	32.75	Geranyl acetate	0.01
28	38.19	1, 3-Benzodioxole, 4-methoxy-6-(2-propenyl)	0.31
29	40.57	Caryophyllene oxide .	0.04
30	42.26	Dillapiole	1.52
31	50.02	2-Pentadecanone, 6, 10, 14-trimethyl	0.04
32	51.35	Pentalenone, 4, 5, 6, 6a-tetrahydro-6, 6a-dimethyl- (3a.alpha, 6.alpha, 6a.alpha.)	0.05
33	51.93	Ethanone, 1-(6, 6-dimethylbicyclo[3.1.0]hex-2-en-2-yl)	0.1
34	52.50	1-(1-cyclohexenyl)-2-propen-1-one	0.04
35	56.49	Phenol, 3-methyl-5-(1-methylethyl)-, methylcarbamate	0.06
36	59.00	2, 7-dinitro-carbazole	0.03
37	70.17	Di-n-octyl phthalate	0.05

growth of some fungal form special was completely inhibited by 100 ppm (Table 5). Parsi Zira essential oil had less antifungal activity than other oils. Its inhibitory effects on *F. oxysporum f. sp. ciceri, F. oxysporum f. sp. melonis* and *F. oxysporum f. sp. lycopersici* isolates were 42.45 to 84/95%, 71.65 to 100% and 48.55 to 100%, respectively (Table 6).

It is evident from Table 4 that cinnamon oil showed fungicidal activity against all the pathogens at 100 ppm concentration except F12, F22 and F37 isolates. In the latter three isolates, the oil exhibited fungicidal activity at 200 ppm. Ajwain and essential oils showed fungistatic activity against all pathogens at studied concentrations (Tables 5 and 6).

Determination of EC_{50}

The EC_{50} values for different essential oils against pathogens were calculated according to the liner relation between inhibitory probit and logarithm of concentration. Results of EC_{50} for different essentials oils against different pathogens are presented in Table 7. The cinnamon essential oil showed remarkable effects

Table 3. Components of *B. persicum* essential oil identified by GC-MS analysis.

S/N	Retention time (min)	Compound	Percentage
1	10.32	α-Thujene	0.33
2	10.47	Cyclohexane, (1-methylethylidene)	0.06
3	10.67	α-Pinene	1.38
4	11.29	Camphene	0.17
5	12.79	β-Pinene	3.04
6	13.54	β.-Myrcene	0.53
7	15.53	para-Cymene	13.09
8	15.71	Limonene	2.85
9	17.37	γ-Terpinene	24.02
10	17.57	Terpinessential oill	0.13
11	18.45	α.-Terpinolene	0.24
12	18.93	cis-sabinene hydrate	0.09
13	19.08	Linalool	0.12
14	20.84	trans-Limonene oxide	0.06
15	21.24	1-methoxy-1,3-cyclohexadiene	0.31
16	21.43	Cyclobutane	0.36
17	22.31	Ethanone, 1-(1,4-dimethyl-3-cyclohexen-1-yl)	0.61
18	22.37	3, 4, 4-Trimethyl-1-penten-3-ol	0.54
19	22.86	Terpinene-4-ol	0.73
20	23.63	Pulegone	1.32
21	25.09	1-(1-Ethyl-2,3-dimethyl-cyclopent-2-enyl)-ethanone	0.06
22	25.22	1, 3-Benzenediol, 4-ethyl	0.05
23	26.61	Cuminaldehyde	20.1
24	26.92	Phenol, 4-(1-methylethyl)	0.22
25	28.12	Cyclopentane, 2-methyl-1-methylene-3-(1-methylethenyl)	3.57
26	28.84	Benzenemethanol, alpha.-propyl	13.01
27	29.17	Benzenemethanol, alpha.-2-propenyl	6.02
28	29.27	1, 3-Dimethylbicyclo[3.3.0]oct-3-en-2-one	1.89
29	29.55	Butanoic acid	0.24
30	29.82	4-hydroxy-3-(1-methylethyl)benzaldehyde	0.1
31	29.92	Camphene	0.33
32	30.21	p-Mentha-1, 4-dien-7-ol	0.2
33	30.48	2-tert-butyl-4, 5-dimethylphenol	0.13
34	30.75	Cumene, trimethyl	0.08
35	31.37	3-(2-oxopyridyl)propanal	0.22
36	32.69	9-epi-β-caryophyllene	0.08
37	33.89	germacrene D	0.1
38	36.49	ar-curcumene	0.08
39	37.01	Zingiberene	0.06
40	37.56	β-Bisabolene	0.21
41	38.15	β.-Sesquiphellandrene	0.12
42	40.49	Caryophyllene oxide	0.38
43	42.03	Dillapiole	0.12
44	44.45	Levomenol	0.15
45	47.52	7-hydroxy-2-methylisoflavone	0.1
46	53.81	Dibutyl phthalate	0.06
47	64.54	Eicosane	0.12
48	70.17	Bis(2-ethylhexyl) phthalate	0.37

Table 4. Antifungal activities of essential oils of *Cinnamomum zeylanicum* against different form specials of *F. oxysporum*.

Concentration (ppm)	Mycelial growth inhibition (%)					
	F. oxysporum f. sp. ciceri		*F. oxysporum f. sp. melonis*		*F. oxysporum f. sp. lycopersici*	
	F3	F6	F12	F22	F27	F37
Control	0^{b}	0^{b}	0^{c}	0^{c}	0^{b}	0^{c}
100	100 (C)^{a}	100 (C)^{a}	37.72 (S)^{b}	44.95 (S)^{b}	100 (C)^{a}	14.67 (S)^{b}
200	100 (C)^{a}	100 (C)^{a}	100 (C) ^{a}	100 (C) ^{a}	100 (C)^{a}	100 (C)^{a}

Values with different letter(s) in the same column are significantly different using Duncan's multiple range tests ($p < 0.05$). Letter in parenthesis indicates fungistatic or fungicidal nature, S = fungistatic and C = fungicidal nature.

Table 5. Antifungal activities of essential oils of *C. copticum* against different form specials of *F. oxysporum*.

Concentration (ppm)	Mycelial growth inhibition (%)					
	F. oxysporum f. sp. ciceri		*F. oxysporum f. sp. melonis*		*F. oxysporum f. sp. lycopersici*	
	F3	**F6**	**F12**	**F22**	**F27**	**F37**
Control	0^{f}	0^{c}	0^{d}	0^{c}	0^{d}	0^{e}
100	77.42 (S)^{e}	80.25 (S)^{b}	83.85 (S)^{c}	88.25 (S)^{b}	82.47(S)^{c}	85.22(S)^{d}
200	78.52 (S)^{d}	100 (S)^{a}	84.40(S)^{c}	100 (S)^{a}	83.85(S)^{b}	86.05(S)^{c}
300	90.27 (S)^{c}	100 (S)^{a}	90.27(S)^{b}	100 (S)^{a}	100 (S)^{a}	88.25(S)^{b}
400	91.10 (S)^{b}	100 (S)^{a}	100 (S)^{a}	100 (S)^{a}	100 (S)^{a}	100 (S)^{a}
500	100 (S)^{a}	100 (S)^{a}	100 (S)^{a}	100 (S)^{a}	100 (S)^{a}	100 (S)$_{a}$

Values with different letter(s) in the same column are significantly different using Duncan's multiple range test ($p < 0.05$). Letter in parenthesis indicates fungistatic or fungicidal nature, S= fungistatic and C= fungicidal nature.

Table 6. Antifungal activities of essential oils of *B. persicum* against different form specials of *F. oxysporum*.

Concentration (ppm)	Mycelial growth inhibition (%)					
	F. oxysporum f. sp. ciceri		*F. oxysporum f. sp. melonis*		*F. oxysporum f. sp. lycopersici*	
	F3	**F6**	**F12**	**F22**	**F27**	**F37**
Control	0^{b}	0^{f}	0^{e}	0^{e}	0^{f}	0^{e}
100	31.60 (S)^{a}	16.60 (S)^{e}	17.15(S)^{d}	19.40 (S)^{d}	21.37 (S)^{e}	31.65 (S)^{d}
200	32.15 (S)^{a}	24.40 (S)^{d}	36.05(S)^{c}	43.30 (S)^{c}	24.95 (S)^{d}	43.30 (S)^{c}
300	36.62 (S)^{a}	38.85 (S)^{c}	59.40(S)^{b}	60.55 (S)^{b}	45.22 (S)^{c}	43.57 (S)^{c}
400	38.57 (S)^{a}	77.15 (S)^{b}	64.95(S)^{a}	100 (S)^{a}	49.12 (S)^{b}	46.60 (S)^{b}
500	42.45 (S)^{a}	84.95 (S)^{a}	71.65(S)^{a}	100 (S) ^{a}	100 (S)^{a}	48.55 (S)^{a}

Values with different letter(s) in the same column are significantly different using Duncan's multiple range tests ($p< 0.05$). Letter in parenthesis indicates fungistatic or fungicidal nature, S = fungistatic and C = fungicidal nature.

against all isolates with exception of F22. However, the height of EC_{50} value was observed for isolate F3 from *B. persicum* (554.99 ppm).

DISCUSSION

Several studies are going on to explore the potential of essential oils as antifungal agents (Rasul et al., 2011; Sami et al., 2010; Delespaul et al., 2000; Giamperi et al., 2002; Lee et al., 2007; Mares et al., 2004; Mishra and Dudey, 1994; Reuveni et al., 1984). In this study, three essential oils have been studied against three forma special of *F. oxysporum*. This fungus is plant pathogenic and is responsible for disease at field conditions. So, considering the importance of essential oils as eco-friendly agents, they were studied against this fungus. The inhibition extent of fungal growth was dependent on the concentration and source of used essential oils. It is interesting to note that cinnamon bark oil exhibited high antifungal activity against all isolates of different forma special of *F. oxysporum* (Table 4) followed by Ajwain oils (Table 5). The literature is also silent on the mode of action of the essential oils when used as postharvest

Table 7. Antifungal activity of essential oils against different fungal isolates. Data are expressed as LC_{50} values in µl per l, representing the concentration to effect 50% of the fungal challenged.

Essential oils	Isolates	EC_{50} (ppm)	Interval confidence at 95% (ppm)		X^2	Slope ± SE
			Lower	Upper		
C. copticum	F_3	56.18	49.58	63.12	9.76	2.66 ± 0.11
	F_6	47.32	44.54	50.11	2.60	2.09 ± 0.10
	F_{12}	129.10	91.92	250.13	20.11	1.31 ± 0.99
	F_{22}	51.90	78.17	180.52	25.77	1.53 ± 0.10
	F_{27}	99.43	79.82	133.60	22.83	2.11 ± 0.11
	F_{37}	79.51	63.29	108.79	6.27	1.15 ± 0.83
C. zeylanicum	F_3	51.84	34.95	110.84	23.54	2.08 ± 0.11
	F_6	41.49	60.30	127.77	18.26	2.01 ± 0.11
	F_{12}	51.91	39.46	64.43	45.81	2.26 ± 0.09
	F_{22}	106.76	43.33	60.83	22.41	3.11 ± 0.11
	F_{27}	53.14	39.60	66.81	50.36	2.21 ± 0.89
	F_{37}	50.23	35.19	65.17	78.42	1.99 ± 0.07
B. persicum	F_3	554.99	506.60	761.10	0.89	0.54 ± 0.04
	F_6	311.60	226.40	428.80	0.88	3.00 ± 0.13
	F_{12}	256.76	240.23	293.61	5.74	2.25 ± 0.12
	F_{22}	229.12	217.71	241.30	0.58	2.43 ± 0.16
	F_{27}	424.06	343.47	571.69	13.92	1.38 ± 0.08
	F_{37}	530.22	382.26	921.15	19.38	0.54 ± 0.07

fungitoxicants (Ttipathi and Dubey, 2004). A substance may inhibit the growth of fungi either temporarily (fungistatic) or permanently (fungicidal). Cinnamon bark essential oil was proved to have fungistatic action at 100 ppm concentration for some isolates and fungicidal action at 200 ppm concentration for all studied isolates. Moreover, Ajwain and Parsi Zira had fungistatic mode of action in all studied concentrations (Tables 5 and 6).

Conclusively, examination of various concentrations in this study showed promising prospects for the utilization of cinnamon bark oil as a sustainable eco-friendly botanical fungicide.

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