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ANTIFUNGAL PROPERTIES OF *CORIANDRUM SATIVUM* EXTRACTS ON *FUSARIUM* SPP. *IN VITRO*

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Fusarium spp. cause significant plant diseases and are responsible for food contamination with mycotoxins. Sustainable crop protection relies on a combination of different measures; among others, plants contain bioactive compounds providing antifungal and antimicrobial properties. Coriander seed extracts have a composition rich in fatty acids, sterols, essential oils, polyphenols etc. Therefore, this study aimed to evaluate the antifungal properties of coriander essential oil and coriander extract on *F. culmorum* and *F. oxysporum* f. sp. *lycopersici in vitro*. The essential oil was obtained by Clevenger apparatus and the extract with the CO_2 extraction method. A potato dextrose agar medium enriched with extracts was inoculated with *Fusarium* spp. discs, incubated and the radial growth of colonies was measured 3 and 7 days after inoculation. Results revealed that the coriander essential oil had higher antifungal properties on *Fusarium* spp. than the coriander extract. No radial colony growth of *F. culmorum* was observed at 1000 µL/L concentration of the essential oil. In contrast, the coriander extract had moderate antifungal properties, which were higher for *F. oxysporum* than for *F. culmorum.* Both plant extracts showed potential to be used as antifungal compounds and thus could help to make plant protection more sustainable.

Keywords: biocontrol, coriander essential oil, coriander extract, Fusarium spp., plant pathogens.

INTRODUCTION

The soil-borne plant pathogen *F. oxysporum* f. sp. *lycopersici* causes tomato wilt, resulting in significant yield losses (Ramirez et al., 2020). In contrast, *F. culmorum* is able to infect a wide range of host plants, mainly cereals (Imriz et al., 2020) and produce mycotoxins, harmful to human (Rosello et al., 2015; Perczak et al., 2019). Increasing concern about the adverse effects of chemical fungicides resulted in an active search for alternative bioactive compounds from plants (Ben-Jabeur et al., 2015). Plants have a wide range of bioactive compounds, providing antifungal, antibacterial, antioxidant, and other properties. They are a natural source of active ingredients which could be used in different industries. For example, previous studies have evaluated various plant extracts for their antifungal activity against *Fusarium* spp. (Hanaa et al., 2011; Mohamed et al., 2017; Nefzi, 2017; Nefzi et al., 2018; Ramirez et al., 2020; Polo et al., 2021). The growth rate of *F. culmorum* was lowered by cinnamon, clove, and oregano oils (Rosello et al., 2015), and essential oils of cinnamon, oregano, and palmarosa were effective against *F. culmorum* and *F. graminearum* (Perczak et al., 2019).

Coriander seeds are a valuable source of biochemical compounds like fatty acids, sterols, tocols, essential oils, polyphenols, and water-soluble constituents (Laribi et al., 2015; Balbino et al., 2021) and are widely used in the food industry. Applying various extraction methods, essential oils and extracts rich in bioactive compounds could be obtained (Anitescu et al., 1997; Ghazamfari et al., 2020). Coriander extracts have recently been studied for their antimicrobial properties against various pathogens. Coriander essential oil was effective against several bacterial strains (Alves-Silva et al., 2013; Zheljazkov et al., 2014; Khalil et al., 2018). A volatile extract of coriander leaves and stems exhibited high antifungal activity against plant patogens such as *Botryotinia fuckeliana*, *Glomerella cingulate*, *F. oxysporum*, and *Pectobacterium carotovorum* (Ikeura and Kobayashi, 2015). These promising results indicate that various forms of coriander extract may also be effective in inhibiting *Fusarium* spp. pathogens. Alternatives to chemical control of fungal pathogens and reduction of mycotoxin production are in constant demand and sustainable techniques are a priority. Therefore, the research aimed to evaluate the antifungal properties of coriander essential oil and extract on *F. culmorum* and *F. oxysporum* f. sp. *lycopersici in vitro*.

RESEARCH METHODS

Coriander seeds (*C. sativum* L.) were collected at the LAMMC Institute of Horticulture, Babtai, Lithuania. The essential oil was prepared using the Clevenger apparatus and the extract was obtained by the CO_2 extraction method (Šernaitė et al., 2020). Antifungal properties were evaluated at the Institute of Plant Protection, University of Natural Resources and Life Sciences, Vienna. Potato dextrose agar containing glucose was prepared according to manufacturer's instructions. Coriander essential oil and extract were poured into the cooled medium at concentrations from 200-1000 µL/L and homogenized on the rotary shaker. Mycelium discs (ø 0.7 cm) were cut from the margins of 7 days old *F. culmorum* and *F. oxysporum* f. sp. *lycopersici*, respectively, and placed in the centre of Petri dishes containing extracts and medium. Petri dishes without extracts were used as a control for the growth of *Fusarium* spp. The plates were incubated at 25 °C and radial colony growth (cm, without pathogen disc) was measured 3 and 7 days after inoculation (DAI).

RESULTS AND CONCLUSIONS

The antifungal properties of coriander essential oil and extract on *F. culmorum* are presented in Figure 1. Coriander extract showed decreasing growth of the pathogen with increased concentrations at 3 DAI. However, the concentration of 200 µL/L exceeded the pathogen growth in control Petri dishes. At 7 DAI, coriander extract showed no antifungal properties at all investigated concentrations. Coriander essential oil had high antifungal properties at 400-1000 µL/L concentrations at 3 DAI. 1000 µL/L treatments resulted in no radial growth of the *F. culmorum* overall. In contrast, at 7 DAI 600-1000 µL/L concentrations remained effective and reduced pathogen growth compared to the control.

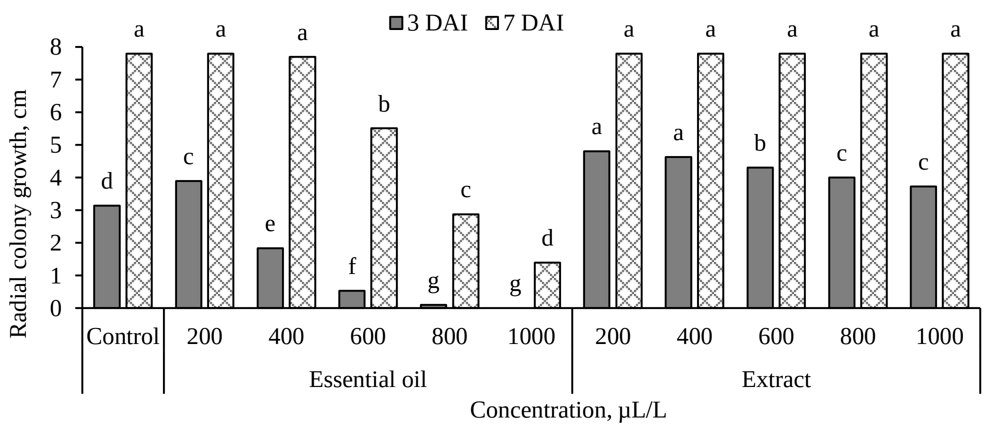

Figure 1. The antifungal properties of coriander essential oil and extract on *F. culmorum* at different concentrations 3 and 7 DAI. Different letters indicate significant differences between treatments ($P < 0.05$).

The antifungal properties of coriander extract on *F. oxysporum* f. sp. *lycopersici* varied (Figure 2). The concentrations of 200 and 800 µL/L were most effective in reducing the pathogen growth after 3 DAI. All extract concentrations showed low antifungal activity at 7 DAI. Coriander essential oil reduced the growth of *F. oxysporum* at both the 3rd and 7th DAI. Radial colony growth decreased with increasing concentration. The concentrations of 800 µL/L and 1000 µL/L had the highest antifungal properties.

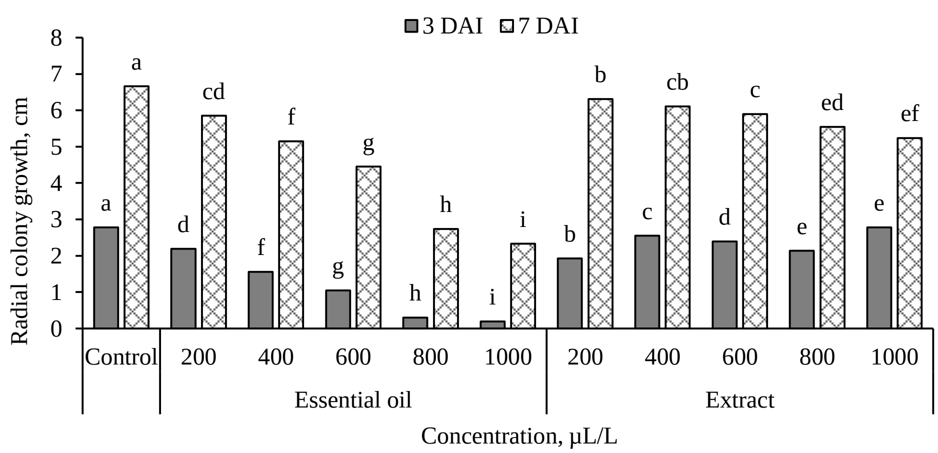

Figure 2. The antifungal properties of coriander essential oil and extract on *F. oxysporum* f. sp. *lycopersici* at different concentrations 3 and 7 DAI. Different letters indicate significant differences between treatments ($P < 0.05$).

Coriander essential oil was found to inhibit *Candida* strains (Silva et al., 2011) and showed promising results as alternative antifungal agent (Laribi et al., 2015). In our study, coriander essential oil showed antifungal activity against *Fusarium* spp. The essential oil had stronger antifungal properties than the coriander extract and suppressed pathogens growth at already lower concentrations. The most effective concentration was 1000 µL/L. Overall, coriander essential oil had a higher antifungal effect on *F. culmorum* at 1000 µL/L. On the opposite, lower concentrations tested had higher antifungal activity on *F. oxysporum* at 7 DAI.

At the same time, coriander extract was more effective against *F. oxysporum* than against *F. culmorum*. It was found that coriander extracts obtained by different extraction techniques had quite a similar composition, however, the more desirable compounds were obtained by CO_2 extraction (Anitescu et al., 1997). Futhermore, Ghazamfari et al. (2020) identified differences in antimicrobial activity of coriander essential oil extracted by microwave-assisted hydrodistillation and conventional hydrodistillation techniques. Therefore, we could assume that *Fusarium* spp. were sensitive to the differences in the composition of coriander extracts in our study, as the antifungal properties were not the same. Our results agree with Ikeura and Kobayashi (2015), whose volatile coriander extract had antifungal activity against *F. oxysporum*. However, the effect was not as high as for other fungal plant pathogens studied. In another study, a minimum inhibitory concentration (MIC) of 1.10 mg/mL of coriander essential oil against *F. oxysporum* was determined (Stevic et al., 2014). This research came to similar results, as a concentration of 1000 µL/L showed the highest antifungal activity against *F. oxysporum* and *F. culmorum*. Coriander essential oil had higher antifungal activity against *F. solani* (MIC=0.97 mg/mL), while the MIC of other *Fusarium* spp. ranged from 2.13 to 4.25 mg/mL (Stevic et al., 2014). Coriander essential oil was found to inhibit the mycotoxin producer *Aspergillus flavus* at significantly higher concentrations than in our study (Lasram et al., 2019).

To conclude, coriander essential oil expressed higher antifungal properties on *Fusarium* spp. *in vitro* than coriander extract. In contrast, the coriander extract had moderate antifungal properties, which were higher on *F. oxysporum* than on *F. culmorum*. The study suggests that the concentration of coriander extract should be increased in future investigations. In any case, the tested ingredients of coriander seeds show an antifungal effect and should be considered for further work on plant pathogen control.

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