

Activity of four local plant extracts against *Fusarium oxysporum* f. sp. *lycopersici*

Original Article

Abstract:

Aqueous, ethanol, and methanol crude extracts of four local plants, namely *Cotula cinerea* (Gartoufa), *Ziziphus lotus* (Sedra), *Peganum harmala* (Harmel), and *Retama raetam* (R'tem), were evaluated for their inhibitory effect on the mycelial growth and spore germination of four strains of *Fusarium oxysporum* f. sp. *lycopersici*. (the causal agent of tomato wilt disease). Alcoholic extracts from *C. cinerea* and *Z. lotus* demonstrated a strong inhibitory effect, reducing radial growth by up to 72.2% and completely inhibiting (100%) spore germination across all four fungal strains. In contrast, the alcoholic extracts of *R. raetam* and *P. harmala* exhibited a moderate inhibitory effect (less than 52%). A Tukey post-hoc test ($p < 0.05$) revealed no significant difference between the efficacy of the ethanolic and methanolic extracts, with only two exceptions. Conversely, the aqueous extracts from all plant materials showed little inhibitory effect on mycelial growth, with inhibition rates ranging from 0% to 16.3%.

Key words:

effect, crude extracts, inhibitory, spore germination, mycelium, *Fusarium*

Apstrakt:

Aktivnost četiri lokalna biljna ekstrakta protiv *Fusarium oxysporum* f. sp. *lycopersici*

Sirovi vodeni, etanolni i metanolni ekstrakti četiri lokalne biljke, i to *Cotula cinerea* (gartoufa), *Ziziphus lotus* (sedra), *Peganum harmala* (harmel) i *Retama raetam* (r'tem), ispitivani su u pogledu njihovog inhibitorynog efekta na rast micelije i klijanje spora četiri soja gljive *Fusarium oxysporum* f. sp. *lycopersici* (uzročnika venača paradajza). Alkoholni ekstrakti *C. cinerea* i *Z. lotus* pokazali su snažan inhibitoryni efekat, smanjujući radijalni rast do 72,2% i potpuno (100%) inhibirajući klijanje spora kod sva četiri soja gljive. Nasuprot tome, alkoholni ekstrakti *R. raetam* i *P. harmala* ispoljili su umeren inhibitoryni efekat (manje od 52%). Tukey-ev post hoc test ($p < 0,05$) pokazao je da ne postoji statistički značajna razlika između efikasnosti etanolnih i metanolnih ekstrakata, uz samo dva izuzetka. S druge strane, vodeni ekstrakti svih biljnih materijala pokazali su slab inhibitoryni efekat na micelijalni rast, sa procentom inhibicije u rasponu od 0% do 16,3%.

Ključne reči:

efekat, sirovi ekstrakti, inhibitoryno, klijanje spora, micelija, *Fusarium*

Nabil Boubakeur

Department of Agriculture Sciences, University
Mohamed Khider of Biskra, Algeria

Karima Kardi

National Institute of Plant Protection, Biskra, Algeria

Mohammed Seghir Mehaoua

Laboratory of Genetics, Biotechnology, and
Valorization of Bio-Resources (GBVB), Faculty of
Exact Sciences and Sciences of Nature and Life,
University Mohamed Khider of Biskra, Algeria
ORCID: 0000-0001-8965-4809

Ayoub Hadjeb

Department of Agriculture Sciences, Laboratory
DEDSPAZA, University Mohamed Khider of Biskra,
Algeria
ORCID: 0000-0003-3981-5066
ayoub.hadjeb@univ-biskra.dz (Corresponding
author)

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Introduction

Greenhouse farming occupies a prominent place among the main agricultural crops in the Ziban region. This cultivation practice accounts for 60% of the national production of vegetable crops, covering more than 7,000 hectares (Adiat et al., 2023). Within this vast expanse, tomato cultivation holds a significant share, accounting for approximately 2,760 hectares of the total area and yielding an average annual production of 347,600 tons (DSA, 2023).

Given its regional and national importance, tomato cultivation faces numerous phytosanitary challenges that can significantly affect both the quantity and quality of its production. *Fusarium* wilt

is one of the most widespread diseases, frequently causing considerable damage (Locke, 2000; Bindu Sharma, 2000; Singh et al., 2009). Consequently, the misuse of chemical plant protection products to control this disease has become a common practice among farmers in the Ziban region.

The use of botanical derivatives as an alternative to chemical products for combating crop pests is currently an approach that is gaining increasing importance worldwide (Cowan, 1999; Campos et al., 2019; Lengai et al., 2020). Plant-derived compounds have been proven to be effective against *Fusarium* species, as demonstrated by studies on aqueous extracts of neem (Farag et al., 2011),



aqueous extracts of 12 plants (Satish et al., 2009), and aqueous and organic extracts of *Sargassum vulgare* (Ammar et al., 2017).

Nevertheless, the majority of bio-pesticides currently used in Algeria target insect and mite pests of crops. Products used against fungi are rare, and those used against soil-borne fungi, particularly *Fusarium*, are even rarer. In this work, we test the hypothesis that local medicinal and aromatic plants contain bioactive secondary metabolites with significant antifungal activity, capable of inhibiting the *in vitro* mycelial growth and spore germination of *Fusarium oxysporum* f. sp. *lycopersici* strains. This would offer a promising, eco-friendly, and locally accessible alternative to chemical fungicides. Furthermore, most of the plants tested in this assay have rarely or never been reported in the context of tomato wilt disease in Algeria.

Material and methods

Plant material

Four plant species, *Cotula cinerea* (Asteraceae), *Ziziphus lotus* (Rhamnaceae), *Peganum harmala* (Zygophyllaceae), and *Retama raetam* (Fabaceae), were collected from two distinct localities, Loutaya (Biskra district) and Taleb Larbi (El-Oued district). After rinsing with tap water, the plants were air-dried for 10 days, after which they were finely ground using mechanical blades. The resulting powder was then stored in plastic containers until ready for use. **Tab. 1.** presents the parts of plants used in this assay.

Fungal strains

Tomato plants exhibiting symptoms of fusarium wilt were collected from the three primary regions where tomato crops are cultivated, namely Ain Nagga, Leghrouss, and Tolga (**Fig. 1**). Subsequently, after sterilization in 3% chlorine solution for 30 seconds and rinsing with sterile distilled water, small sections of the root of each plant were placed in petri dishes containing potato dextrose agar (PDA) and incubated at a temperature of 25 °C. After ten days, the fungal strains were isolated and purified using the same culture medium. These strains were then stored until use.

Table 1. parts of plants used for extraction

	Roots	Stem	Leaf	Flowers	Seeds
<i>C. cinerea</i>	+	+	+	+	-
<i>P. harmala</i>	+	+	+	+	-
<i>R. raetam</i>	-	+	+	+	-
<i>Z. lotus</i>	-	+	+	-	+

Extracts preparation

Aqueous extracts: 10 g of plant powder were soaked in 100 mL of distilled water for 48 hours, then filtered through a Whatman paper No. 1. The resulting solution was centrifuged at 4000 rpm twice for 10 minutes, and the supernatant was stored at -4 °C until ready to use.

The assay employed ethanol and methanol as the most commonly used solvents (Cowan, 1999) to acquire crude extracts. 20 g of each plant powder was soaked in 150 mL of the solvents for at least 48 hours. The resulting slurry was subjected to dual filtration using Wattman paper No. 1 to remove impurities, followed by drying in a vacuum chamber at 40 °C and 1 psi (Taylor et al., 1996). The final product was weighed and diluted with the same extraction solvent, yielding a solution at 350 mg/mL. These solutions were stored in opaque containers at -4 °C until ready to use.

Effect on mycelium growth

The impact of each extract on the growth of fungi mycelium was examined through implementation of the well diffusion method, as an alternative to the disc diffusion method described by Espinet et al. (2007), Maida et al. (2008), and Benlembarek et al. (2022), and outlined by Brown et al. (1987). On one side of the Petri dishes, containing 15 mL of PDA medium, wells measuring 6 mm in diameter were created using a sterilized microtip. These wells were subsequently filled with 5, 10, and 20 µL of each extract, and a 30-minute diffusion period at 37 °C was allowed. Following this, 6 mm mycelial discs obtained from a 7-day-old culture were placed on the opposite side of the wells, 3.5 cm from the well. The subsequent incubation occurred at 25 °C. The growth of mycelium was then measured daily for 5 days, and three replicates of each treatment were conducted. Three control tests were conducted using the solvents (distilled water, ethanol, and methanol) at the same concentrations.

The inhibitory zone was calculated as:

$$\text{inhibition \%} = \left(\frac{A-B}{A} \right) \times 100$$

A = mycelium growth of the controlled test

B = mycelium growth of the treatment

Effect on spore germination

All strains of the fungi were grown in a simple medium, “agar + water,” to enhance the spore production. After 10 days of incubation at 25 °C, spore suspensions were prepared as described in Sarpeleh et al. (2009) and Baba et al. (2023), with the final concentration of 2×10^5 spores/mL. A milliliter of the suspension was pipetted into a set of

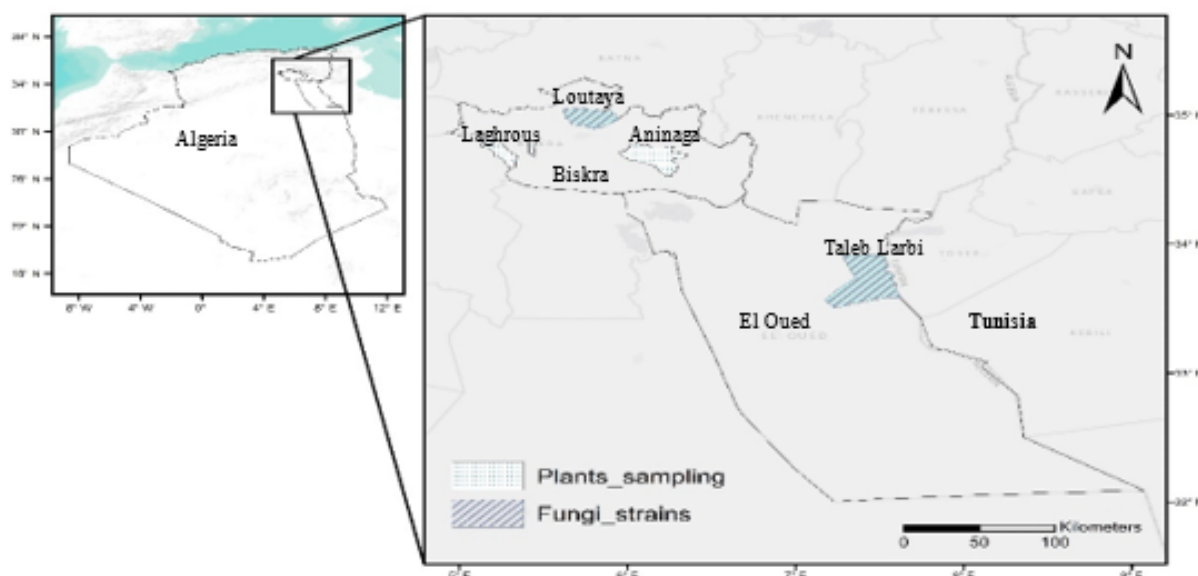


Fig. 1. Plants and fungi sampling zones

Eppendorf tubes, and a specific amount of alcoholic extract was added to each tube to achieve the three targeted concentrations of 1%, 5%, and 10% (w/v), with three repetitions and a negative control.

Following a 24-hour incubation period, a drop of Amannlactophenol was added to each tube to halt germination and enable the examination of 100 spores at 40× magnification using an optical microscope. The percentage of germination was calculated as:

Germination % = (number of spores germinated / number of spores observed) x 100

In this test, pure extracts were used instead of the 350 mg/mL concentration used in the initial test, as both ethanol and methanol have a detrimental effect on spore germination at 10%.

Statistical analysis

A one-way analysis of variance and a Tukey's post hoc test with a significance level of $p \leq 0.05$ were performed by the R software to compare treatment means and assess the performance of ethanolic and methanolic extracts used in this study.

Results

Strains identification

Macroconidial shape, dimensions, and number of septa were used as primary characters to identify the fungal strains, following the *Fusarium* identification keys of Booth (1971) and Leslie & Summerell (2006).

Effect on mycelium growth

In this work, the inhibitory effect of ethanolic and methanolic crude extracts from four spontaneous plants on the mycelial growth of four strains of *Fusarium oxysporum* f. sp. *lycopersici* was evaluated.

Analysis of variance revealed no significant difference between the treatments and the control samples at low doses (5 and 10 µL/well) for six out of eight crude extracts. However, both *C. cinerea* extracts (ethanolic and methanolic) did show a reducing effect on the mycelial radial growth of all fungal strains, with a p -value less than 0.05.

At the highest dose (20 µL/well), all crude extracts exhibited a highly significant inhibitory effect on all strains of *F. oxysporum* f. sp. *lycopersici*. The inhibitory effect of the crude extracts (**Tab. 2**) revealed two major groups of efficiency. The first group, consisting of two species (*C. cinerea* and *Z. lotus*), showed the largest inhibition zones with both solvents, ranging from 53% to 72%. Within this group, the ethanolic crude extract of *C. cinerea* was the most efficient product against all strains of *F. oxysporum*. The second group was represented by *P. harmala* and *R. raetam*, for which the inhibition zones of both solvent extracts did not exceed 50%, except for the ethanol extract of *R. raetam* against the Lichana strain.

Effect on spore germination

In this assay, alcoholic extracts of the selected plant species were used at three concentrations (1%, 5%, and 10%) to evaluate their inhibitory effect on the different strains of *F. oxysporum* sp. (**Tab. 3** and

Table 2. Extracts effect on mycelium growth in the fifth day

		Extracts effect on mycelium growth by strain (mean (cm), inhibitory zone (%))							
		Lichana		Horaya		Mansoria		Nebka	
Solvent	Plant	Mean	inhib	mean	inhib	mean	inhib	mean	inhib
Ethanol	<i>C. cinerea</i>	1.2	65.4	1.07	72.2	1.37	63.1	1.3	67.2
	<i>Z. lotus</i>	1.43	58.6	1.23	67.8	1.73	53.1	1.6	59.7
	<i>P. harmala</i>	2.07	43.1	2.03	47	2.3	37.8	2.1	47.1
	<i>R. raetam</i>	1.67	51.9	2	47.8	1.97	46.8	2.5	37
	Controlled t	3.47	—	3.83	—	3.7	—	3.97	—
Methanol	<i>C. cinerea</i>	1.6	56	1.6	57.9	1.5	60.9	1.57	61.2
	<i>Z. lotus</i>	1.43	60.5	1.53	59.6	1.4	63.5	1.73	57
	<i>P. harmala</i>	2.03	44	2.1	44.7	2.43	36.5	2	50.4
	<i>R. raetam</i>	2.33	35.9	2.33	38.6	2.43	36.5	2.43	39.7
	Controlled t	3.63	—	3.8	—	3.83	—	4.03	—

4). At a low concentration (1%), both ethanol and methanol extracts of *Z. lotus* and *C. cinerea* showed strong inhibitory effects on all four strains tested, ranging from 91% to 99.7%. At high concentrations (10%), the extracts of these two plants almost completely inhibit fungal germination, with inhibition ranging from 99.3 to 100%. The ethanol and methanol extracts of *P. harmala* and *R. raetam* didn't exhibit any significant effect on germination at a low concentration of 1%; however, their inhibitory effect increased with increasing concentration. At the highest concentration (10%), their effect ranges from 52.6% to, exceptionally, 87%.

Solvent effect

Three solvents—water, ethanol, and methanol—were used in this assay to assess the impact of their crude extracts on the mycelial growth of *Fusarium oxysporum* f. sp. *lycopersici*. The aqueous extracts at concentrations of 5, 10, and 20 µl/well did not exhibit a significant inhibitory effect on the mycelial growth of any of the four strains tested. The highest inhibitory effect, 16.3%, was observed after 5 days of incubation with the *C. cinerea* extract, while the *R. raetam* extract showed no effect.

Alcoholic extraction proved to be the most effective approach against the growth rate of all fungal strains tested. Tukey's post hoc test, conducted to compare the mean inhibitory effects of ethanol and methanol extraction, revealed no significant difference between the two solvents for either mycelial radial growth (Fig. 2) or spore germination (Fig. 3), with a few exceptions.

Discussion

In this work, the inhibitory effect of crude extracts from four local plants on the mycelial growth and spore germination of *Fusarium oxysporum* f. sp. *lycopersici*, a major causal agent of tomato diseases in the region, was evaluated. *Cotula cinerea* and *Z. lotus* alcohol extracts proved to be highly effective at very low doses against pathogenic mycelial growth, with inhibition rates ranging from 56% to 72.2% and from 53.1% to 67.8%, respectively. The same plants also exhibited a strong inhibitory effect on spore germination at low concentrations (1%), with rates ranging from 91% up to 99.7%.

Even though the antibacterial effects of these two last plants are well documented (Mebarki, 2018; Bekkar et al., 2023), the literature on their antifungal properties is very limited. Both Salhi et al. (2017) and Archaoui et al. (2022) reported a low inhibitory effect of the water extract of *C. cinerea* against three different *Fusarium* species. Benahmed & Djebbar (2017) reported a total inhibition of the mycelium growth of *Aspergillus niger* caused by the essential oil of the same plant at a concentration of 1 % (v/v). El-Khateeb & Elsherbiny (2013) note that methanolic extracts of *Z. spina* Christi inhibited the mycelial growth of *F. oxysporum* by 64.44%. All the above results agree with our findings.

Benahmed & Djebbar (2017) reported a complete inhibition of *Aspergillus niger* spore germination using the essential oil of *C. cinerea* at concentrations of 1/250 and 1/100. Archaoui et al. (2022) noted that the hemicellulose fraction of the same plant inhibits the germination of *F. oxysporum* f. sp. *albedinis* up to 84.45% at a concentration of 1 mg/mL.

Table 3. Effect of ethanol extracts

Spore germination by strain (%)					
Plant extract	Concentration	Lichana	Horaya	Mansoria	Nebka
<i>C. cinarea</i>	1%	3.3	6.3	7.0	6.0
	5%	1.3	2.3	4.3	3.3
	10%	0.6	0.0	0.6	1.0
	Control	79.0	83.6	75.0	82.0
<i>Z. lotus</i>	1%	2.0	1.6	6.6	1.0
	5%	0.3	2.3	2.6	0.6
	10%	0.3	0.0	0.3	1.0
	Control	79.0	83.6	75.0	82.0
<i>P. harmala</i>	1%	77.0	74.6	75.3	83.0
	5%	73.3	75.6	71.0	78.3
	10%	20.3	15.6	28.3	55.0
	Control	79.0	83.6	75.0	82.0
<i>R. raetam</i>	1%	76.0	85.3	81.6	74.0
	5%	73.3	46.6	28.6	76.0
	10%	27.3	26.6	19.0	38.0
	Control	79.0	83.6	75.0	82.0

Table 4. Effect of methanol extracts

Spore germination by strain (%)					
Plant extract	Concentration	Lichana	Horaya	Mansoria	Nebka
<i>C. cinarea</i>	1%	9.0	6.6	2.6	1.6
	5%	1.6	0.3	0.6	2.1
	10%	1.0	0.3	0.3	0.6
	Control	93.0	79.3	76.3	82.3
<i>Z. lotus</i>	1%	0.6	3.0	6.0	1.3
	5%	0.3	2.0	3.3	0.3
	10%	0.3	0.3	0.6	0.3
	Control	93.0	79.3	76.3	82.3
<i>P. harmala</i>	1%	88.3	83.3	75.6	73.6
	5%	79.3	70.3	56.0	58.6
	10%	54.6	47.3	33.6	20.6
	Control	93.0	79.3	76.3	82.3
<i>R. raetam</i>	1%	75.3	84.0	79.3	70.3
	5%	59.6	80.3	46.3	59.0
	10%	45.3	39.3	24.0	13.0
	Control	93.0	79.3	76.3	82.3

Both *P. harmala* and *R. raetam* exhibited a moderate effect on the mycelial growth of the fungi, respectively, between 36.5% and 50.4% and between 35.9% and 51.8%. Sarpeleh et al. (2009) noted that the ethanolic and methanolic crude extracts of *P. harmala* had no effect on the mycelium growth of

various fungal species, including *F. oxysporum*. The same author reported a high activity of water extracts against the mycelium growth of the same fungus; however Hajji et al. (2020) and Behidj-Benyounes et al. (2014) reported a moderate effect of the seeds' essential oils of *P. harmala* on the mycelium growth of *F. oxysporum*. Namsi et al. (2018) reported an inhibition rate of 77.4% against *Neofusicoccum mangiferae* at a concentration of 1000 mg/100 mL.

Three solvent extracts were used in this assay to evaluate their inhibitory effects on the mycelium growth of four strains of *F. oxysporum* (tomato wilt). The aqueous extracts were the least effective against the tested fungi. Our results are in contrast with those of many authors (Haouala et al., 2008; Satish et al., 2009; Sangoyomi et al., 2010; Baka, 2014; Mugao et al., 2020; Kursu et al., 2022), who reported a high inhibitory effect of plant water extracts on various species of *Fusarium* spp. These results are probably caused by the high concentrations of crude products tested by these authors (up to 60%). Cowan (1999) stated that aromatic and saturated organic molecules are the main antibiotic compounds and are often obtained by alcoholic extraction.

Alcoholic crude extracts proved to be the most effective against the growth rate of all strains of *F. oxysporum* sp. tested in this assay, with inhibitory zones ranging from 35.9% to 72.2%. These results agree with those of many authors. Farzana Ashrafi et al. (2014) cite an inhibitory effect of ethanol and methanol extracts of six plants against *F. oxysporum* sp. of 100% in concentration of 25%. Dissanayake (2014) notes that methanol extracts of neem, ginger, and wild basil inhibit the growth of *F. oxysporum* sp. mycelium by up to 90% at a concentration of 25%. Satish et al. (2009) reported that ethanol and methanol extracts of eleven plants were more effective on the mycelium growth of *F. oxysporum* f. sp. *lycopersici* than other solvents, including water. However, (Satish et al., 2009; Farzana Ashrafi et al., 2014) they reported that methanol-extracted products were more effective against mycelial growth than ethanol extracts, our results showed that most treatments did not show a significant difference between ethanol and methanol

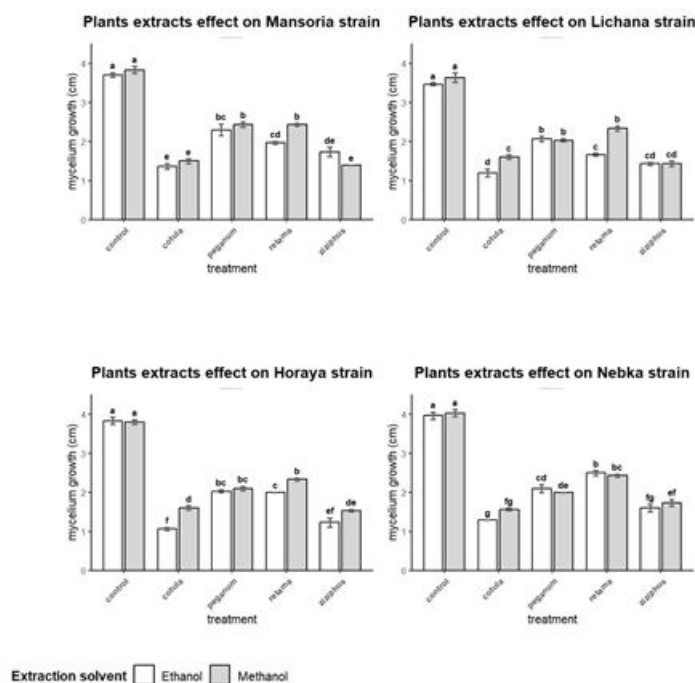


Fig. 2. Effect of alcoholic extracts on the radial growth of the different strains (dose 20 µL/well)

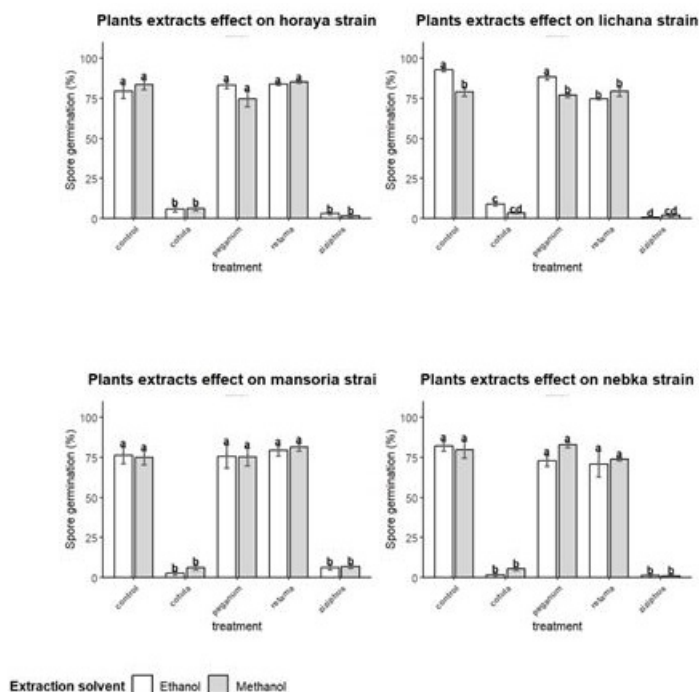


Fig. 3. Effect of alcoholic extracts on spore germination of the different strains at 1% concentration

extracts.

Conclusion

In this study, we demonstrated the strong inhibitory activity of alcoholic extracts from two understudied local plant species, *Cotula cinerea* and *Ziziphus lotus*, against the mycelial growth and spore germination of *Fusarium oxysporum* f. sp. *lycopersici*, the causal agent of tomato *Fusarium* wilt. The percentage inhibition of mycelial growth ranged from 56% to 72.2%, while spore germination was suppressed by 91% to 99.7% even at low extract concentrations. The alcoholic extracts of the two other species tested in this assay, *Peganum harmala* and *Retama raetam*, showed a medium inhibitory effect (less than 50% with one exception) against the mycelium growth of the fungi and less than 30% of spore germination with the lowest concentration.

Among the three solvents used in this assay, water extracts were the least effective at inhibiting mycelial growth of tomato wilt disease-causative agents, with an inhibitory zone of no more than 16.3%. The ethanol and methanol extracts show no statistical differences regarding the inhibition of mycelium growth of *F. oxysporum* sp.

Further studies are necessary to determine the chemical composition of *C. cinerea* and *Z. lotus* extracts, to identify the compounds active against the fungi, and to assess the potential for using these compounds as a means of control in the field.

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References

Ammar, N., Nefzi, A., Jabnoun-Khiareddine, H., & Daami-Remadi, M. (2017). Control of *Fusarium* dry rot incited by *Fusarium oxysporum* f. sp. *tuberosi* using *Sargassum vulgare* aqueous and organic extracts. *Journal of Microbial & Biochemical Technology*, 9, 200–208. <https://doi.org/10.4172/1948-5948.1000366>

Archoui, C., Gafa, N., Hasni, H., Mebarki, L., Boulenouar, A., & Benlarbi, L. (2022). In vitro antifungal effect of *Cotula cinerea* extracts against *Fusarium oxysporum* f. sp. *albedinis* and soil population assay. *Advances in Biology & Earth Sciences*, 7(2), 104–115.

El-Khateeb, A. Y., & Elsherbiny, E. A. (2013). Phytochemical analysis and antifungal activity of fruit leaves extracts on the mycelial growth of fungal plant pathogens. *Journal of Plant Pathology and Microbiology*, 4(9), 1–6.

Baba, M. L., Essghaier, B., Robledo-Mahón, T., Abidine, M. M., Aranda, E., Sánchez, J., Elemine, B. O., Gallego, E., Sebai, K., & Vadel, A. (2023). First report of *in vitro* biological agent to biocontrol of date palm stipe rot affected by *Fusarium brachygibbosum* by using *Pergularia tomentosa* L., aqueous extract. *Journal of Ecological Engineering*, 24(9), 373–384. <https://doi.org/10.12911/22998993/169381>

Baka, Z. A. M. (2014). Biological control of the predominant seed-borne fungi of tomato by using plant extracts. *Journal of Phytopathology and Pest Management*, 1(3), 10–22.

Behidj-Benyounes, N., Dahmene, T., Allouche, N., & Laddad, A. (2014). Phytochemical, antibacterial and antifungal activities of alkaloids extracted from *Peganum harmala* (Linn.) seeds of South of Algeria. *Asian Journal of Chemistry*, 26(10), 2960–2964. <https://doi.org/10.14233/ajchem.2014.16138>

Bekkar, N. E. H., Meddah, B., Keskin, B., & Sonnet, P. (2023). *Zizyphus lotus* and *Ruta chalepensis* essential oils for combating antimicrobial resistance in pathogenic clinical bacteria and fungi. *Nova Biotechnologica et Chimica*, 22(1), e1519. <https://doi.org/10.34135/nbc.1519>

Benahmed, F., & Djebbar, N. (2017). The effect of *Cotula cinerea* essential oil on spore germination, mycelial growth and on sporulation of phytopathogenic fungi: *Aspergillus niger*. *Applied Biology in Saharan Areas*, 1(2), 23–29.

Benlembarek, K., Lograda, T., Ramdani, M., Figueredo, G., & Chalard, P. (2022). Chemical composition and biological activities of *Anethum graveolens* L. essential oil from Algeria. *Journal of Essential Oil Bearing Plants*, 25(4), 728–740. <https://doi.org/10.1080/0972060X.2022.2113149>

Booth, C. (1971). *The genus Fusarium*. Commonwealth Mycological Institute.

Brown, A. E., Finlay, R., & Ward, J. S. (1987). Antifungal compounds produced by *Epicoccum purpurascens* against soil-borne plant pathogenic fungi. *Soil Biology and Biochemistry*, 19(6), 657–664. [https://doi.org/10.1016/0038-0717\(87\)90044-7](https://doi.org/10.1016/0038-0717(87)90044-7)

Cowan, M. M. (1999). Plant products as antimicrobial agents. *Clinical Microbiology Reviews*, 12(4), 564–582.

Dissanayake, M. (2014). Inhibitory effect of selected medicinal plant extracts on phytopathogenic fungus *Fusarium oxysporum* (Nectriaceae) Schlecht. Emend. Snyder and Hansen. *Annual Research & Review in Biology*, 4(1), 133–142. <https://doi.org/10.9734/ARRB/2014/5777>

- Direction des Services Agricoles (DSA).** (2023). *Bilan final de la campagne agricole 2022–2023*.
- Espinel-Ingroff, A., Arthington-Skaggs, B., Iqbal, N., Ellis, D., Pfaller, M. A., Messer, S., Rinaldi, M., Fothergill, A., Gibbs, D. L., & Wang, A.** (2007). Multicenter evaluation of a new disk agar diffusion method for susceptibility testing of filamentous fungi with voriconazole, posaconazole, itraconazole, amphotericin B, and caspofungin. *Journal of Clinical Microbiology*, 45(6), 1811–1820. <https://doi.org/10.1128/JCM.00134-07>
- Farag, R. M., Abdou, Z. A., Salama, D. A., Ibrahim, M. A. R., & Srour, H. A. M.** (2011). Effect of neem and willow aqueous extracts on fusarium wilt disease in tomato seedlings: Induction of antioxidant defensive enzymes. *Annals of Agricultural Sciences*, 56(1), 1–7. <https://doi.org/10.1016/j.aos.2011.05.007>
- Ashrafi, N. F., Ara, S. I., & Shamim, S.** (2014). Antifungal activity of selected medicinal plant extract on *Fusarium oxysporum* Schlecht the causal agent of *Fusarium* wilt disease in tomato. *American Journal of Plant Sciences*, 5(18), 2665–2671. <https://doi.org/10.4236/ajps.2014.518281>
- Hajji, A., Bnejdi, F., Saadoun, M., Ben Salem, I., Nehdi, I., Sbihi, H., Alharthi, F. A., El Bok, S., & Boughalleb-M'Hamdi, N.** (2020). High reserve in δ -tocopherol of *Peganum harmala* seeds oil and antifungal activity of oil against ten plant pathogenic fungi. *Molecules*, 25(19), 4569. <https://doi.org/10.3390/molecules25194569>
- Haouala, R., El-Ayeb, A., Khanfir, R., & Boughanmi, N.** (2008). Aqueous and organic extracts of *Trigonella foenum-graecum* L. inhibit the mycelial growth of fungi. *Journal of Environmental Sciences*, 20, 1453–1457.
- Kursa, W., Jamiolkowska, A., Wyrostek, J., & Kowalski, R.** (2022). Antifungal effect of plant extracts on the growth of the cereal pathogen *Fusarium* spp. — An in vitro study. *Agronomy*, 12(12), 3204. <https://doi.org/10.3390/agronomy12123204>
- Leslie, J. F., & Summerell, B. A.** (2006). *The Fusarium laboratory manual*. Blackwell Publishing.
- Maida, C. M., Milici, M. E., Trovato, L., Oliveri, S., Amodio, E., Spreghini, E., Scalise, G., & Barchiesi, F.** (2008). Evaluation of disk diffusion method compared to microdilution method in susceptibility testing of anidulafungin against filamentous fungi. *Journal of Clinical Microbiology*, 46(12), 4071–4074. <https://doi.org/10.1128/JCM.01112-08>
- Lakhdar, M.** (2018). Traditional uses, phytochemistry and biological activities of *Cotula cinerea* Del: A review. *Tropical Journal of Pharmaceutical Research*, 17(2), 365–373.
- Mugao, L. G., Muturi, P. W., Gichimu, B. M., & Njoroge, E. K.** (2020). *In vitro* control of phytopathogens using crude extracts and essential oils. *International Journal of Agronomy*, 2020, 1–10. <https://doi.org/10.1155/2020/8845692>
- Namsi, A., Sihem, B., Chaieb, I., Jemni, M., & Berri, I.** (2018). In vitro antifungal activity of medicinal plant against *Neofusicoccum mangiferae*. *Journal of New Sciences, Agriculture and Biotechnology*, 51(2), 3148–3153.
- Salhi, N., Mohammed Saghir, S. A., Terzi, V., Brahmi, I., Ghedairi, N., & Bissati, S.** (2017). Antifungal activity of aqueous extracts of some dominant Algerian medicinal plants. *BioMed Research International*, 2017, 1–6. <https://doi.org/10.1155/2017/7526291>
- Sangoyomi, T. E., Asiedu, R., & Ekpo, E. J. A.** (2010). Effects of ten plant extracts on mycelial growth and conidial production of four fungi associated with yam tuber rot. *African Journal of Root and Tuber Crops*, 8(1), 24–30.
- Sarpeleh, A., Sharifi, K., & Sonbolkar, A.** (2009). Evidence of antifungal activity of wild rue. *Journal of Plant Diseases and Protection*, 116(5), 208–213. <https://doi.org/10.1007/BF03356312>
- Satish, S., Raghavendra, M. P., & Raveesha, K. A.** (2009). Antifungal potentiality of plant extracts against *Fusarium* sp. *Archives of Phytopathology and Plant Protection*, 42(7), 618–625. <https://doi.org/10.1080/03235400701287578>
- Sharma, B., & Kumar, P.** (2009). *In vitro* antifungal potency of plant extracts against *Fusarium oxysporum*. *International Journal of Green Pharmacy*, 3(1), 63–65. <https://doi.org/10.4103/0973-8258.49377>
- Taylor, R. S. L., Edel, F., Manandhar, N. P., & Towers, G. H. N.** (1996). Antimicrobial activities of southern Nepalese medicinal plants. *Journal of Ethnopharmacology*, 50(2), 97–102. [https://doi.org/10.1016/0378-8741\(95\)01335-0](https://doi.org/10.1016/0378-8741(95)01335-0)