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Antifungal activity of *Solanum elaeagnifolium* extracts against *Fusarium oxysporum* f. sp. *radicis-lycopersici*

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This study explored *in vitro* the inhibitory effect of *Solanum elaeagnifolium* leaves, stems, and fruits extracts against *Fusarium oxysporum* f. sp. *radicis-lycopersici* (FORL). Aqueous and organic extracts (used at 1, 2, 3, and 4%) were added to molten Potato Dextrose Agar (PDA) medium. After pathogen inoculation, cultures were incubated at 28°C/7 days. All extracts tested showed a strong antifungal activity against FORL using poisoned food technique. The variation depends on the concentrations tested and the organic solvent used for extraction. For aqueous extracts, the leaves extract used at 4% exhibited the highest antifungal potential, where FORL growth was decreased by 87.50%, relative to the untreated control, compared to 75 and 50% achieved using fruits and stems extracts at 4%, respectively. The highest antifungal activity of organic extracts was registered at the highest concentration used (4%). FORL was found to be more sensitive to leaf extracts than to those from fruits and stems. Among the four organic extracts tested, ethanolic, methanolic, and chloroform fractions were the most active against FORL growth than ether, with an inhibitory effect of about 87.50%. These results indicate that native *Solanum elaeagnifolium* plants may be exploited as a potential source of biologically active allelochemicals against FORL.

Keywords: Antifungal activity, Extract, *Fusarium oxysporum* f.sp. *radicis-lycopersici*, Mycelial growth, *Solanum elaeagnifolium*

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Introduction

The tomato cultivation occupies a prominent place in the Algerian agricultural economy, as in many countries. Thus, although there has been a significant development in recent decades, average yields are still low and quite remote from those found in other Mediterranean countries (Tunisia, France, Morocco, Spain) for tomato producers. However, tomato cultivation knows serious problems this premiere knows serious problems that are causing considerable losses, related to the pathogens' pressure, including harmful sponger interference roots[1]. Thus, FORL (Jarvis and Shomaker) responsible of *Fusarium* crown and root rot, is known among soil-borne diseases the most devastating of the tomato crop in the worldwide[2] and one of the most serious fungal diseases and more difficult to control, which is a veritable scourge for this interest economic culture, thereby eliminating these ubiquitous pathogens is not easy because their saprophytic power and their ability to colonize non-host plants allow it to survive in adverse conditions, and they are able to persist in infested soil for more than 10 years in the absence of tomato plant[3]. However, despite the economic losses that they cause, the control of these pathogens is still limited to prophylactic measures, from where there does not exist currently any really effective means to completely control this devastating disease, of which epidemic character, added to the strong potentialities of conservation of pathogen in soil; the absence of really resistant vegetable genotypes; as well as the inefficiency of the chemical methods (fungi develop resistance) and their abusive use causing pollution of the environment, disturb microbial community of soil and affecting the consumers health, all that has lead to the use of other alternative methods such as the biological control seen to minimize the damage induced by this pathogens without adverse effects on the environment or on the consumer health[4,5].

Today, more attention is increasingly focused on the use of a large variety of plants' aqueous and organic extracts, from various parts like leaves, roots,

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fruit, and seeds, containing antifungal properties against plant pathogenic fungi[6-8], especially in modern agriculture. Antifungal compounds from plant origins have little or no side effects on non-target soil microorganisms. Out of the thousand plant species having medicinal importance, only a small portion have been investigated phytochemically and pharmacologically. In this regard, a few investigations were performed to screen the antifungal properties of some botanical extracts against FORL[9,10].

In various previous studies, the antifungal potential of plant-derived allelochemicals has been demonstrated[11-13]. In fact, aqueous and organic extracts from *Withania somnifera* stems, leaves, and fruits were screened for their ability to suppress the growth of FORL, where the most active antifungal compounds were detected in the butanolic fraction from stem extracts[14]. Acetone extracts from *Cestrum laevigatum*, *Nicotiana glauca*, *Solanum mauritianum*, *Lantana camara*, *Datura stramonium*, *Ricinus communis*, and *Campuloclinium macroephalum* were also screened for their ability to suppress ten phytopathogenic fungi, including *F. oxysporum*[15]. It was also shown that methanolic extracts from Thymus vulgaris and *Zingiber officinale* were strongly active against *F. oxysporum*, *P. aphanidermatum*, and *R. solani* infecting tomato[16]. The ethanolic extract of *D. stramonium* leaf exhibits maximum inhibition against *Rhizoctonia solani* and *Fusarium solani*[17]. The antimicrobial activity of wild *Solanaceae* species has also been reported in various studies[18,19].

S. elaeagnifolium is a wild *Solanaceae* plant, commonly called silver leaf nightshade, bitter apple, and tomato weed. In Algeria, farmers call it "echouka", which means thorn, because of the multiple spines on the stem[20]. This species is widely distributed in America and propagated in Australia, Egypt, Greece, India, Israel, Zimbabwe, Sicily, South Africa, the Maghreb countries, and Spain[21-23]. It is considered an invasive species[24] and one of the extremely interesting medicinal plants with pharmaceutical applications[25-27], such as antiinflammatory, the treatment of sore throats, an antiseptic agent, toothaches, and gastrointestinal disorders[21]. Its extract is considered to be beneficial for human health and/or for the control of plant diseases and pests[28]. It contains toxic and pharmacological properties due to the presence of many biologically active compounds such as alkaloids, solanine, solasonine and solasodine[29,30]. For exemple, solasodine is used as a natural precursor. In laboratory, this compound is transformed to a steroidien compose to be used in fabrication of contraceptives or cortico-steridiens drugs[29,30]. Traditionally, it is used in many drugs for the treatment of tooth and throat pains and several problems that affect repertory ways[31]. Further, it was also shown that the crude extracts from *S. elaeagnifolium* have an efficient activity on nematodes[32,33] and an antibiotic activity on several pathogenic bacteria like *Staphylococcus aureus* and *Escherichia coli*[34-37]. The successive EtOH extract of *S. elaeagnifolium* seeds had promising inhibition efficacy against *Erwinia carotovora,* causing potato rot[8].

However, few reports were focused on its antifungal activity against plant pathogenic fungi. In fact, it was demonstrated that the crude extracts of roots and leaves of *S. elaeagnifolium* were effective against the growth of *Fusarium oxysporum* f. sp. *albedinis*, the causal agent of Bayoud disease[38]. Biological control of *Fusarium* wilts of tomato (FOL) by the application of endophytic bacterial isolates from Silver Leaf (*S. elaeagnifolium*) showed good results[39].

However, *S. elaeagnifolium* causes serious problems for farmers, which is considered the most invasive and agricultural weed species for many important cultural plants, such as cotton, tomato, and potato[40]. It is a severe threat to sustainable crop yields, where it enters into competition for nutrients (mineral salts) and water sources with many vegetal species, causing losses to gain considerable. Further, it was shown that it is toxic for cattle and causes respiratory disease to the farmers. *S. elaeagnifolium* was also reported to be a reservoir for various viruses[41], nematodes, and insects[42].

Given what has been stated above, the aim of the present study is to investigate the *in vitro* antifungal activity of leaf, stem and fruit aqueous and organic extracts from *S. elaeagnifolium* wild plants, collected from Algeria against FORL on the one hand, and to find a real solution to this invasive plant so difficult to control, by using them as biofongicide in biological control of *Fusarium* Crown and Root Rot disease in tomato over the world on the other hand.

Materials and Methods

Plant material

The plant of *S. elaeagnifolium,* healthy and fresh leaves, stems, and fruits (Fig. 1) were collected from different regions of Oran, province of northwestern Algeria, in September 2016. The plant sample was identified by Prof. Harche M, a botanist and Ex-director of the Laboratory of Plant and Microbial Productions and Valuations (LPMPV) at USTO-MB University, with the voucher specimens (SE22)

Fig. 1 — *Solanum elaeagnifolium* a) leaves, b) stems, and c) fruits.

deposited at LPMPV. Fresh materials collected were washed thoroughly under running tap water, followed by distilled water to remove any dirt. After washing and cleaning, the material was shade dried at room temperature for a week and finely ground into a fine powder with the help of a grinder. Powdered leaves, stems, and fruits were stored in airtight bottles for further use in the preparation of the extract.

Fungal agent

In this study, the FORL strain used was isolated from tomato plants cultivated in greenhouse and showing a high level of pathogenicity based on typical symptoms of *Fusarium* Crown and Root Rot (FCRR) disease. Fungal cultures were grown on Potato Dextrose Agar (PDA) medium and incubated at 28°C for 7 days before being used for antifungal bioassays.

Preparation of aqueous and organic extracts

The preparation of aqueous extracts was done by homogenization of dried leaves, stems, and fruit powder from *S. elaeagnifolium* in sterilized distilled water (SDW) (1:10 w/v) for 24 h at room temperature. Extracts were filtered through a double-layered muslin cloth, followed by Whatman No.1 filter paper, and then passed through a 0.22 µm micro-filter pore size to remove bacteria. Filtrates were stored at 4°C and were generally used within a week to avoid any prospective chemical alterations[43].

For organic extracts preparation, dried leaves, stems, and fruit powder from *S. elaeagnifolium* were homogenized in different solvents (1:10 w/v), ethanol, ether, methanol, and chloroform separately (Table 1), then incubated at room temperature for 24 hours. After incubation, extracts were filtered through two layers of muslin cloth and centrifuged at 3800xg for 30 min at 4°C. The solvent phase of the extracts was evaporated in a vacuum at 40°C using a Rotavapor. A sample of each dry residue (1 mg) obtained was individually dissolved in 1 mL of sterilized distilled water for antifungal activity analysis, stored at 4°C, and used within 4 days.

Table 1 — Solvents used for active component extraction[44]

Sterilized distilled water	Ethanol	Methanol	Ether Chloroform
Tannins Terpenoides Saponins	Alcaloides Flavonols	Flavones	Coumarins Flavonoides

Antifungal activity assay

From the two types of extract, aqueous and organic, at different concentrations, 1, 2, 3, and 4% (v/v) were prepared from *S. elaeagnifolium* leaves, stems, and fruits.

The screening antifungal activity of extracts against the mycelial growth of FORL was tested *in vitro* by the poisoned food technique[45].

Starter culture of FORL was prepared in PDA medium. Plant Extract of different concentrations and from different parts of the plant (leaves, stems, and fruits) was mixed with 100 mL of cooled molten media (PDA) in a conical flask and poured into Petri plates (9 cm in diameter) and allowed to solidify at room temperature. A mycelium disk of 5 mm diameter was cut out from the periphery of an actively growing fungus (4-7 days old culture) with the help of a pre-sterilized cork borer and aseptically plated at the centre of each Petri plate. A plate without the extract act was used as a negative control.

All Petri plates were incubated at 28°C for seven days. After incubation, the effect of the extract was determined by measuring the radial growth of fungi in the test plate and comparing it with the control plate. The colony diameter of the fungus in each plate was measured in cm. The antifungal activity was assessed in terms of percentage inhibition. Percentage growth inhibition (%) of FORL was calculated according to the following formula:

Growth inhibition (%) = I % = C-T/C X 100

Where C = Growth of mycelium in control plate (cm) and T = Growth of mycelium in treatment plate (cm), the mean of three plates is considered the final reading.

Each individual treatment was replicated thrice. The whole experiment was repeated twice.

Statistical analysis

All Data treatment was done with Microsoft Excel 2007 and completed with one-way analysis of variance (ANOVA) associated with the mean comparison test of Student-Newman-Keuls (SNK) (at $P \leq 0.05$) using SPSS (Statistical Package for the Social Sciences) version 16.0. Each individual treatment was replicated thrice. The whole experiment was repeated twice.

Results

Antifungal activity of *S. elaeagnifolium* aqueous extracts

A significant reduction in FORL colony diameter was shown depending on the *S. elaeagnifolium* aqueous extracts used, plant organs, and concentrations tested. A significant interaction was detected between both fixed factors. All extracts tested were shown to be effective in suppressing FORL *in vitro* growth, but with a varied degree depending on the extracts' origin and concentrations used. Data given in Fig. 2 and showed that for leaves aqueous extract, the concentration used at 4% exhibits the highest inhibitory effect, where FORL mycelia growth decrease was about 87.50% relative to the untreated control. However, the aqueous extract of fruits was found to be more active at 4%, inducing a respective reduction of pathogen growth by 75%. For the stem's aqueous extract, the greatest inhibition was registered at 4% also, concentration leading to 50% decrease in FORL growth as compared to the untreated control, while with the other concentrations, growth inhibition ranged between 31.25 and 43.75% (Table 2).

It was also shown that when the concentration of the aqueous extracts increases, they exhibit a higher antifungal effect on FORL mycelia growth for all aqueous extracts tested and from different organs, and that leaves extracts are more effective against FORL, followed by fruits and stems extracts. So it was demonstrated that all *S. elaeagnifolium* aqueous extracts tested were found to be active against FORL, with the leaves' aqueous extract applied at 4% being the most effective, leading to an 87.50% decrease in pathogen radial growth.

Antifungal activity of *S. elaeagnifolium* organic extracts

ANOVA analysis showed that FORL colony diameter, noted after 7 days of incubation at 28°C, varied significantly depending on the organs used for extraction, the organic extracts tested, and the concentrations used. A significant interaction between the three fixed factors was also detected (at $P \leq 0.05$).

All organic extracts tested exhibited antifungal activity and inhibited pathogen radial growth, as compared to the untreated control. In fact, Ethanol

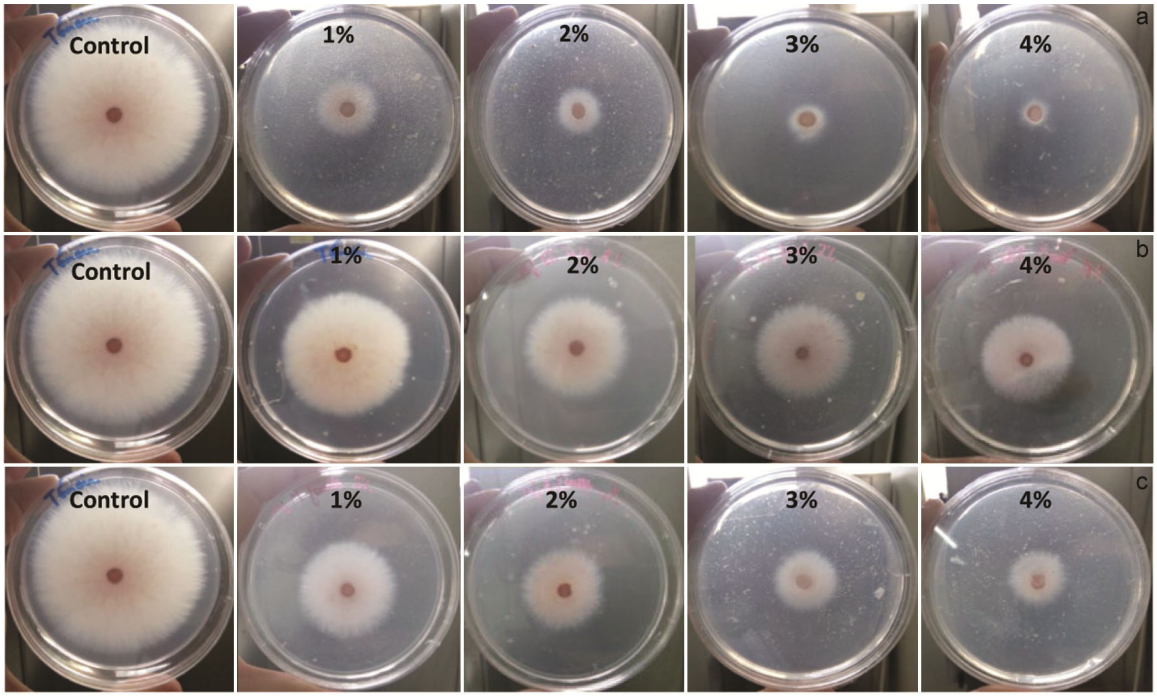

Fig. 2 — FORL colonies grown on PDA medium supplemented with aqueous extracts from *S. elaeagnifolium*, a) leaves, b) stems, and c) fruits tested at four concentrations (1, 2, 3 and 4% v/v). Negative control: untreated control (PDA+SDW).

Table 2 — Inhibition percentage of aqueous extract of *S. elaeagnifolium* against FORL

S. elaeagnifolium	Concentration of aqueous extract / inhibition (%) 1%	2%	3%	4%
Leaves	68.75	75	81.25	87.50
Stems	31.25	37.50	43.75	50
Fruits	56.25	62.50	68.75	75

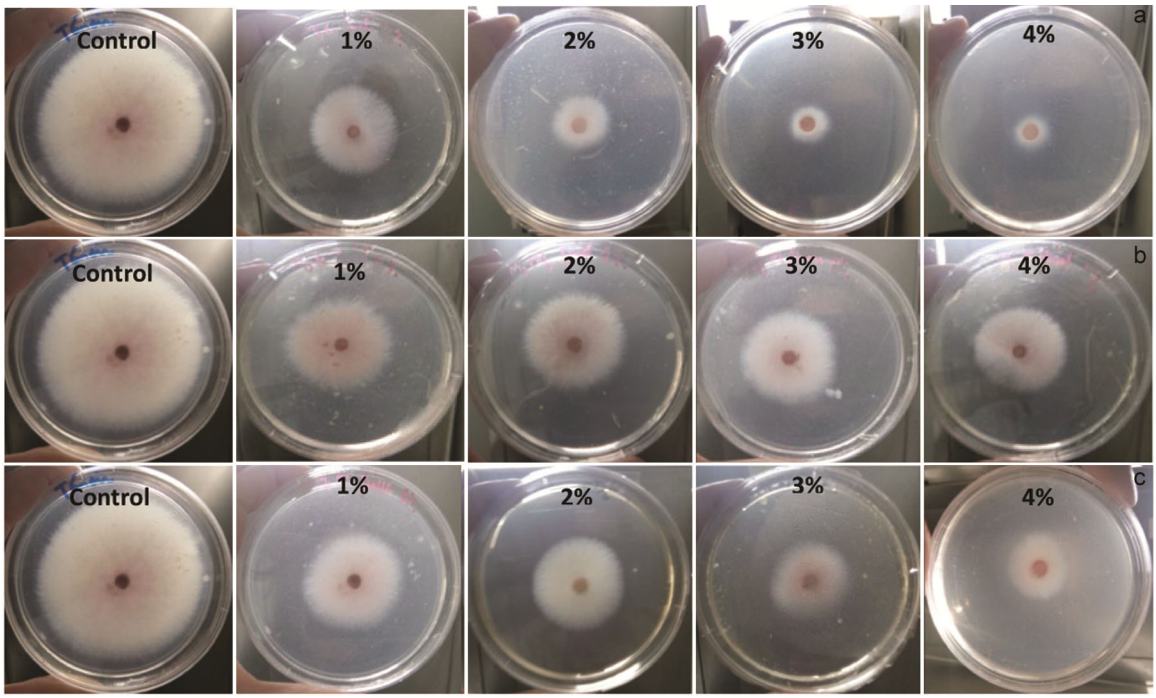

Fig. 3 — FORL colonies grown on PDA medium supplemented with ethanolic extract from *S. elaeagnifolium*, a) leaves, b) stems, and c) fruits tested at four concentrations (1, 2, 3 and 4% v/v). Negative control: untreated control (PDA+SDW).

Table 3 — Showing inhibition percentage of *S. elaeagnifolium* organic extract against FORL

S. elaeagnifolium	Concentration of ethanol extract / inhibition (%) 1%	2%	3%	4%
Leaves	66.25	67.50	81.25	87.50
Stems	46.25	50	55	63.75
Fruits	47.50	56.25	66.25	82.50
	Concentration of methanol extract / inhibition(%)			
Leaves	67.50	68.75	81.25	87.50
Stems	46.25	50	56.25	65
Fruits	46.25	55	65	83.75
	Concentration of chloroform extract / inhibition(%)			
Leaves	67.50	68.75	81.25	87.50
Stems	46.25	52.50	56.25	62.50
Fruits	46.25	56.25	62.50	67.50
	Concentration of ether extract / inhibition (%)			
Leaves	65	68.75	62.50	81.25
Stems	47.50	50	55	63.75
Fruits	48.75	53.75	50	85

extracts from *S. elaeagnifolium* stems, fruits and leaves, used at 4%, had also suppressed pathogen growth (Fig. 3) by 52.50, 62.50, and 87.50% relative to control, respectively, whereas their antifungal potential decreased to 46.25**,** 46.25, and 55% when applied at 1% (Table 3).

The pathogen inhibition reached 65, 83.75, and 87.50% using *S. elaeagnifolium* methanol extracts from stems, fruits, and leaves used at 4%, respectively, compared to 46.25, 46.25, and 67.50% achieved using these extracts at 1% (Fig. 4, Table 3).

For chloroform fractions, FORL radial growth was 62.50, 67.50, and 87.50% lesser than the untreated control when grown on PDA supplemented at 4% with stems, fruits, and leaves chloroform fractions in contrast to 46.25, 46.25, and 67.50% noted when these extracts were tested at 1% (Fig. 5, Table 3).

For Ether extract, FORL radial growth was 63.75, 81.25, and 85% lesser than the untreated control when grown on PDA supplemented at 4% with stems, fruits and leaves chloroform fractions in contrast to 47.50,

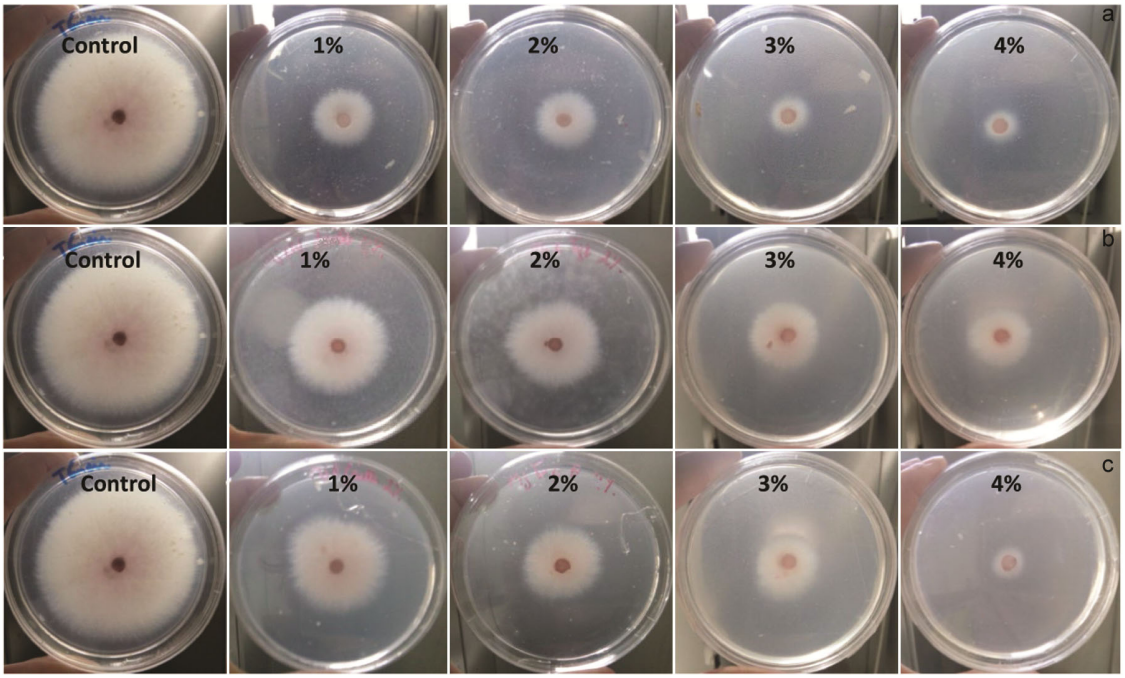

Fig. 4 — FORL colonies grown on PDA medium supplemented with methanolic extract from *S. elaeagnifolium*, a) leaves, b) stems, and c) fruits tested at four concentrations (1, 2, 3 and 4% v/v) recorded after 7 days of incubation at 25°C. Negative control: untreated control (PDA+SDW).

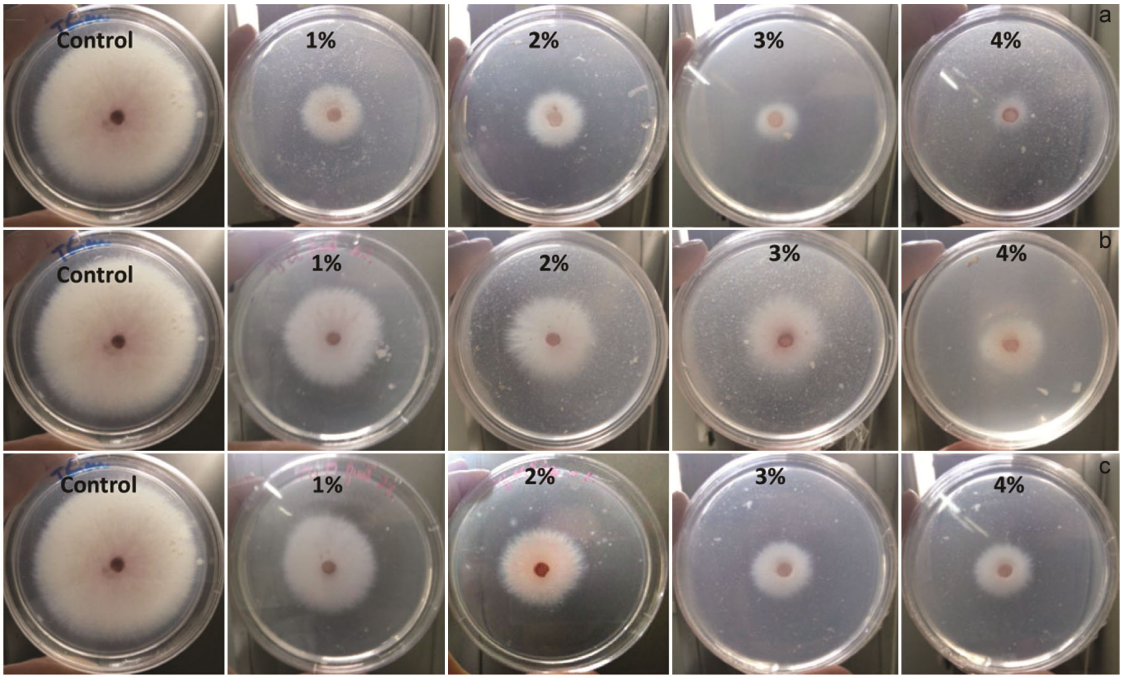

Fig. 5 — FORL colonies grown on PDA medium supplemented with chloroform extract from *S. elaeagnifolium*, a) leaves, b) stems, and c) fruits tested at four concentrations (1, 2, 3 and 4% v/v). Negative control: untreated control (PDA+SDW).

48.75, and 65% noted when these extracts were tested at 1% (Fig. 6, Table 3).

In fact, all organic extracts tested were shown to be effective in suppressing FORL *in vitro* growth, but with a varied degree depending on the type of solvent used, the origin of the extracts, and the concentrations used (Fig. 7). Data given in Fig. 8 showed that for all extracts, the concentration used at 4% exhibits the highest inhibitory effect on FORL mycelia growth. It was also shown that leaves extract from ethanol,

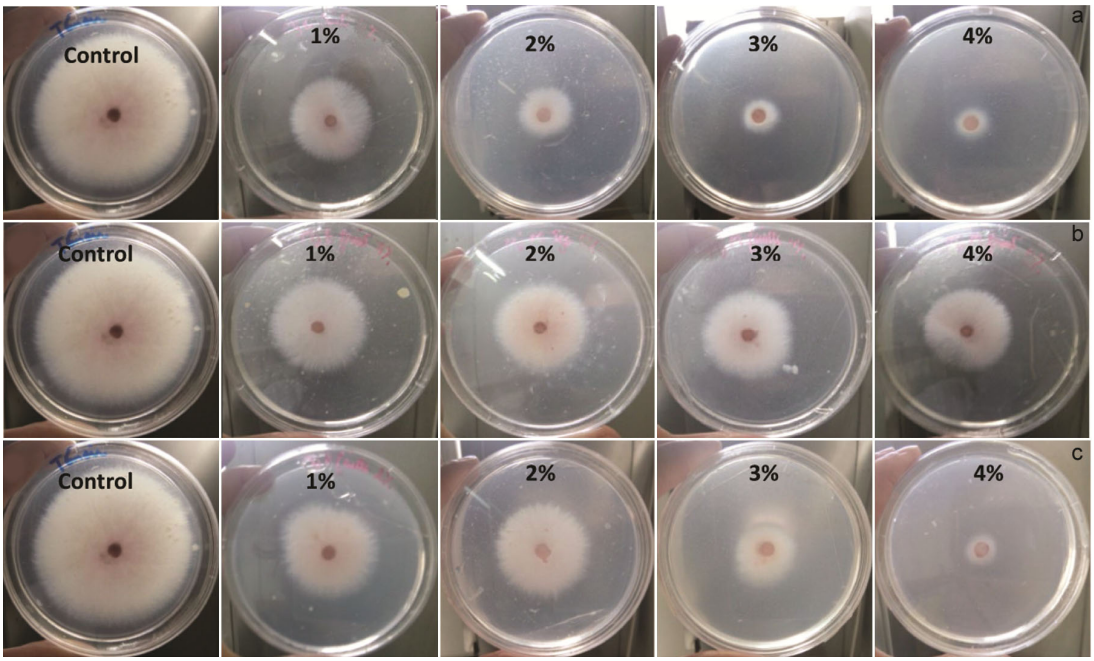

Fig. 6 — FORL colonies grown on PDA medium supplemented with ether extract from *S. elaeagnifolium*, a) leaves, b) stems, and c) fruits tested at four concentrations (1, 2, 3 and 4% v/v). Negative control: untreated control (PDA+SDW).

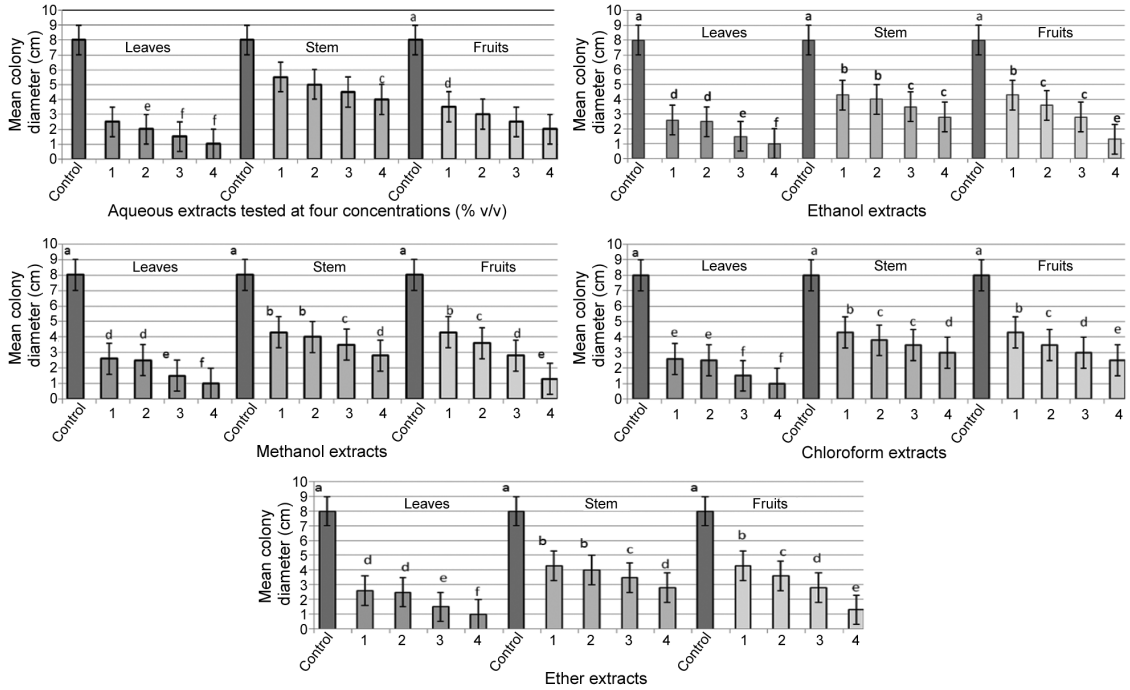

Fig. 7 — Mean colony diameter (cm) of FORL growth under the effect of aqueous and organic extracts (Ethanol, Methanol, Chloroforme and Ether) from *S. elaeagnifolium* leaves, stems, and fruits. For extracts from each organ used, bars sharing the same letter are not significantly different according to Student-Newman-Keuls (SNK) test (at $P \leq 0.05$).

methanol, and chloroform had the highest inhibitory effect (87.50%), where fruits extract from ether had the highest inhibition (85%) than stems and leaves.

In the present study, it was shown that *S. elaeagnifolium* leaf extracts were more active against FORL than those from fruits and stems. Similarly, distilled water, ethanol, methanol, and chloroform extracts were found to be relatively more effective in suppressing FORL growth than ether extracts. In addition, for concentrations used, it was

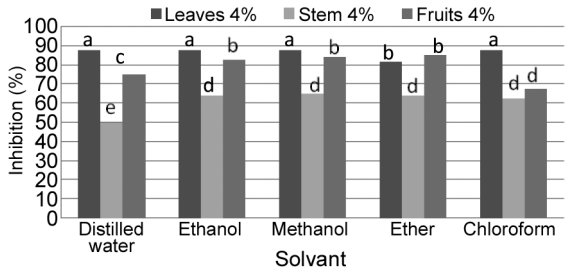

Fig. 8 — Inhibitory effect (%) of aqueous and organic extracts from *S. elaeagnifolium* leaves, stems and fruits, at concentration of 4% on FORL growth. For extracts from each organ used, bars sharing the same letter are not significantly different according to Student-Newman-Keuls (SNK) test (at $P \leq 0.05$).

shown that the highest mycelial growth inhibition of the targeted pathogen was mainly reached at the highest concentration applied at 4%.

Discussion

The search for new alternative methods, effective and with greater selectivity, such as the biological control, seen to minimize the damage induced by this pathogen without adverse effects on the environment or on consumer health, is necessary today. In fact, the use of natural compounds from plants is safer and could be taken as a biological control of plant pathogens based on their antifungal activity without being phytotoxic.

Many plant extracts were tested against FOL and FORL[46]. In this study, aqueous, ethanol, methanol, chloroform, and ether extracts from S. elaeagnifolium leaves, stems, and fruits were screened *in vitro* at four concentrations (1, 2, 3, and 4%) for their ability to suppress FORL growth.

Then, for a successful isolation of compounds with different ranges of polarity, it was so important to use solvents with varying polarity in the extraction procedure.

Results showed that distilled water, ethanol, methanol, and chloroform leaves extract induced the highest mycelial growth inhibition (87.50%) compared to the ether extracts. This later exhibits a higher inhibition (85%) from fruit extracts. These results are in agreement with findings from previous studies. Indeed, Khrishnamoorthy *et al.*[47] demonstrated that antifungal activity is pathogen-specific and depends on solvent, crude extract concentration, temperature, and plant parts used for the extraction of secondary metabolites. This could be attributed to their differences in chemical nature, polarity, and solubility of active bio-molecules in each used solvent.

This antifungal potential may be due to the presence of some polar constituents such as glycosides, saponins, tannins, alkaloids, flavonols, and flavonoides[48], which could be present in this kind of fraction, as shown in the previous Table 1.

All *S. elaeagnifolium* aqueous extracts had significantly reduced FORL mycelial growth at all concentrations tested. The leaves extract was found to be the most active at 4% leading to 87.50% lower growth relative to the untreated control. However, for the other organs, the highest antifungal potential was noted at 4% (50 and 75% achieved using stems and fruits extracts, respectively). Similarly, Amer *et al.*[35] and Bouslamti *et al.*[37] showed that aqueous extracts from S. *elaeagnifolium* leaves and fruits had an antifungal and antibacterial effect.

This significant antifungal effect could probably be attributed to some bioactive polar and water-soluble metabolites. Indeed, phytochemical analysis of *S. elaeagnifolium* extract effects due to the presence of some secondary metabolites such as Tannins, Terpenoids, and Saponins[48], which are known to have an antimicrobial effect[48].

However, few data are available concerning the use of wild *S. elaeagnifolium* metabolites for FCRR control in tomato, where some wild Solanaceae extracts were used against several fungi causing plant diseases. Moreover, Boukhobza[39] demonstrated that the crude extracts of roots and leaves of *S. elaeagnifolium* were effective against the growth of *Fusarium oxysporum* f.sp. *albedinis*, the causal agent of Bayoud disease. Bhawana *et al.*[17] showed that the ethanolic extract of *D. stramonium* leaf exhibits maximum inhibition against *Rhizoctonia solani* and *Fusarium solani.* Nefzi *et al.*[14] demonstrated that aqueous and organic extracts from *Withania somnifera* stems, leaves, and fruits were screened for their ability to suppress the growth of FORL. On the other hand, Onalar and Yilar[49] showed that flower aqueous extracts from *Trachystemon orientalis* L. have completely inhibited FORL mycelial growth when applied at the concentrations 5, 7, 10, and 20%. Bouslamti *et al.*[37] demonstrate the antifungal effect of *S. elaeagnifolium* extracts.

For Ethanol, Methanol, and Chloroform extracts, those from leaves and fruits were found to be more effective against FORL at a concentration of 4% where fungus radial growth was reduced by 87.50% relative to 65% obtained using stems extracts.

Ethanol extracts from *S. elaeagnifolium* leaves had significantly inhibited the growth of the target fungus

by 87.50%. Ethanol fruit extract had limited pathogen growth by 62.50% and that from stems by 52.50% at the highest concentration tested (4%). Similarly, Horace *et al.*[48] showed that ethanol leaves extracts from *S. elaeagnifolium* exhibit an antifungal effect.

Methanol extracts from *S. elaeagnifolium* leaves had significantly inhibited the growth of the target fungus by 87.50%. Ethanol fruit extract had limited pathogen growth by 83.75 % and that from stems by 65% at the highest concentration tested (4%). Similarly, Horace *et al.*[48] showed that methanol leaves extracts from *S. elaeagnifolium* exhibit an antibiotic effect against several human pathogenic bacteria.

For chloroform extracts, those from leaves were found to be more effective against FORL, where fungus radial growth was reduced by 87.50% relative to 67.50 and 62.50% obtained using fruits and stems extracts, respectively.

Ether extracts exhibit a higher inhibition (85%) from fruit extracts than from the other parts of plants (leaves and stems). Similar results were shown by Abdel Nasser *et al.*[8], where *S. elaeagnifolium* fruit extracts had an antibacterial effect on *Galleria mellonella* and *Erwinia carotovora* pv. *Carotovora*. Different extracts of *S. elaeagnifolium* were tested for their antibacterial activity. The lipid fraction (ether extract) showed the highest antibacterial activity against *S. aureus, E. coli* and *Pseudomonas*[35].

Therefore, the Ethanol, Methanol, Chloroform, and Ether extracts showed significant antifungal potential against FORL mycelial growth, but with varied levels depending on the types of organic extracts, the plant material used for extraction, and the concentrations tested. Similar results were found by Balavivekananthan *et al.*[36], where ethanol, chloroform, and ether extracts from *S. elaeagnifolium* leaves and stems exhibit an antibacterial effect against several human pathogenic bacteria as *E. coli, S. aureus*, *Klebsiella oxytoca, Bacillus cereus, Serratia macescens, Klebsiella pneumonia, Enterobacter amnigenus, Staphylococcus lentus*, *Staphylococcus haemolyticus* and *Brevibacterium paucivorans.* Horace *et al.*[48], showed that methanol leaves extracts from *S. elaeagnifolium* exhibit an antibiotic effect against several human pathogenic bacteria.

Few studies have reported the antifungal activity of *S. elaeagnifolium* organic extracts (methanol, chloroform, ethanol, and ether) against FORL. In fact, Khan and Nasreen[50] showed that *W. somnifera* methanolic extracts reduce the colony diameter of *F. oxysporum* by 71.11% as compared to the untreated control.

In this study, it was demonstrated that FORL was more sensitive to *S. elaeagnifolium* ethanol, methanol, chloroform, and water fractions compared to ether fractions. The strongest inhibition, of about 87.50% occurred using leaves' ethanolic, methanolic, and chloroform extracts applied at 4%.

Several works reported the antibacterial and antifungal effects of *S. elaeagnifolium* aqueous and organic extracts against several human pathogenic bacteria[35,8,48] and a few phytopathogenic fungi. Hence, these studies are very important in discovering effective but low-cost antifungal compounds.

Although the antibacterial activities of *S. elaeagnifolium* against human pathogenic bacteria were studied, there is little information about the antifungal activity of *S.elaeagnifolium* against phytopathogenic fungi.

Conclusion

The present work is the first report on the *in vitro* antifungal activity of ethanol, methanol, chloroform, and ether extracts from *S. elaeagnifolium* leaves, stems, and fruits, against FORL. Results showed that *S. elaeagnifolium* extracts exhibited a significant antifungal effect against this pathogen. Leaves, ethanol, methanol, and chloroform extracts were found to be the most bioactive, mainly when used at the highest concentration (4%). Bioactive compounds from *S. elaeagnifolium* extracts, showing antifungal activity, could serve as a potential source of naturally derived fungicides, after being proven by studying their efficacy *in vivo* on FORL, the causal agent of tomato wilt and root rot. Additionally, purification and chemical identification of their bioactive compounds may elucidate more accurately the mechanisms of action involved in pathogen inhibition.

Conflict of interest

The authors declare that there are no conflicts of interest.

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