Original Research Article

Antifungal activity and Fourier Transform Infrared Spectrometric Characterization of Aqueous Extracts of *Acacia senegal* and *Acacia tortilis* on phytopathogenic fungi

ABSTRACT

Objective: To evaluate the *in vitro* antifungal activity of aqueous extracts of *Acacia senegal* (*A. senegal*) and *Acacia tortilis* (*A. tortilis*) against three phytopathogenic fungi (viz., *Altenaria alternata* [*A. alternata*], *Helminthosporium rostratum* [*H. rostratum*], and *Fusarium solani* [*F. solani*]).

Methods: Crude aqueous extracts of *A. senegal* and *A. tortilis* at 1%, 2.5%, and 5% concentrations were used for screening. Antifungal activities of the extracts were evaluated against three phytopathogenic fungal strains (*A. alternata, H. rostratum,* and *F. solani*) by poisoned food technique. Scanning electron microscopy (SEM) of the treated and untreated mycelia was employed to analyze the ultrastructural changes and Fourier Transform Infrared (FTIR) spectrometry analysis was performed to identify important functional groups.

Results: Aqueous extract of *A. tortilis* at high concentrations exhibited moderate inhibitory activity against the selected fungal strains. The aqueous extract of *A. senegal* showed no effect on *A. alternata*, while exhibited very mild activity against *H. rostratum* and *F. solani* at high concentrations (2.5% and 5%). Scanning electron microphotographs of the untreated fungal cells showed no structural changes (well–defined mycelium and conidia without any distortion), whereas the treated cells showed structural distortions, twisted and wrecked mycelia, and showed the presence of vesicles on the surface. FTIR analysis showed the presence of important functional groups such as alcohols, carboxylic acids, and aromatic compounds.

Conclusion: Results from this study indicate that the aqueous extracts of both *A. senegal* and *A. tortilis* have the potential to be used as natural fungicidal agents in the management of diseases caused by plant pathogenic fungi.

Keywords: Acacia senegal; Acacia tortilis; Anti-fungal activity; Aqueous extracts; Plant pathogenic fungi; Fourier Transform Infrared Spectrometric (FTIR); Scanning Electron Microscopy (SEM).

1. INTRODUCTION

Acacia senegal (L.) Willd (*A. senegal*) and *Acacia tortilis* (*A. tortilis*) commonly known as gum acacia are leguminous dryland trees widely distributed in arid and semiarid ecosystems of sub-Saharan Africa, Australia, and the Middle East [1]. These legumes have remarkable adaptability to drought, alkalinity, and salinity and substantially contributes to the replenishment of soil fertility in the arid regions [2, 3]. Both plants produce a myriad of primary and secondary metabolites, which possess inhibitory properties against an array of microorganisms [4-8]. Traditionally, the gum from both *Acacia* species have been used as a food additive [9, 10]. In addition to their use in food industry, they possess immense medicinal properties and have been used to treat inflamed skin surface, burns, sore throat, diarrhea, dysentery, gonorrhea, urinary tract infections, leprosy, and renal diseases [11-14]. Furthermore, they are also used as antioxidants, antitussive and astringent agents [8, 14, 15].

Several studies have reported the antifungal activity of *Acacia* species (for example *A. nilotica, A. saligna, A. catechu,* and *A. arvensis*) [13, 16-20]. The extracts of the *Acacia* plants were found to exhibit potent activity against wide range of fungal species including *Pythium aphanidermatum* [17], *Altarnaria brassicae* [19], *Fusarium oxysporum ciceris* [19], *Rhizoctonia solani*[16, 19], *Candida albicans* [13, 18], *Trichophyton rubrum* [20], *Microsporum gypseum* [20], and *Epidermophyton floccosum* [20], *Fusarium culmorum* [16], *Penicillium chrysogenum* [16].

Alternaria alternata (A. alternata) is a necrotrophic fungi pathogen that causes diseases in a variety of economically important crops, including apple, broccoli, cauliflower, carrot, citrus, pear, potato, rice, strawberry, tomato, and tobacco, ornamental plants and a number of weed species [21]. It generally affects the aerial parts of the plants such as leaves, petioles, floral parts and seeds [22, 23]. *Helminthosporium rostratum* (*H. rostratum*) is another phytopathogenic fungi that affects an array of the plants including rice, maize, corn, sorghum, and millet [24]. *Fusarium solani* (*F. solani*) is a highly fungal species and has been known to infect several crops including peas, beans, potatoes, and many types of cucurbits [25].

Although several studies have evaluated the antimicrobial activities of gum exudates against a broad range of pathogens [7, 26-29]. Antifungal activity against the plant pathogenic fungi viz., *A. alternata*, *H. rostratum,* and *F. solani* remains highly elusive. Therefore, the present study explored the *in vitro* antifungal activity of aqueous extracts of *A. senegal* and *A. tortilis* against three plant pathogenic fungi (*A. alternata*, *H. rostratum,* and *F. solani*). Moreover, Fourier-transform infrared (FTIR) spectroscopy analysis for the identification of phytochemicals and scanning electron microscopic (SEM) studies of fungi treated with extracts were undertaken to characterize the ultrastructural damage caused by the aqueous extracts from both the plants.

2. MATERIAL AND METHOD

2.1 Plant Materials

The gum of *A. senegal* and *A. tortilis* were procured from authorized suppliers (forever drug store and Bin mingash respectively, Riyadh, Saudi Arabia). Gum resins were kept at -80^{0}C freezer overnight following which they were crushed into a fine powder using mortar and pestle in a 40 µM mess, regular blender, and electric sieve system. After pulverization, the gum resins were stored at -20^{0}C in separate, well-labeled containers until further processing.

2.2 Preparation of Aqueous Plant Extracts

First, the fresh dry plant materials were crushed then 30 gm of the crushed material were soaked in 300 mL distilled water (10% w/v) at 37^0C in closed containers for 24 hours. The soaked material was macerated with 50 mL distilled water (10% w/v) in separate labeled glass bottles and then subjected to shaking (250 rpm at 45^0C for 24 hours) in an orbital shaker (Sartorius Certomat IS, Germany). The supernatant was filtered through Whatman's (No. 1) filter paper. The extracts were then concentrated and dried under reduced pressure and 40^0C using rotary evaporator (Rotavapor® R-215, BUCHI). All the filtered extracts were preserved aseptically in glass bottles at 4^0C until further use.

The sterile aqueous extracts were diluted with distilled water (10% w/v) to obtain different final concentrations (1, 2.5, 5 mg/mL) on the base of the dry weight of dried aqueous extracts. Reconstituted aqueous extracts were passed through 0.45 µM bacterial filter papers (Millipore Inc., Riyadh, Saudi Arabia) before using them for in vitro assay.

2.3 Fungal Material

The plant-fungal strains (*H. rostratum, F. solani* and *A. alternata*) used in this study were obtained from the Department of Plant Protection, College of Food and Agricultural Sciences, King Saud University, Riyadh, Saudi Arabia. All the fungal strains were maintained on Potato dextrose agar.

2.4 *In vitro* Antifungal Activity

The antifungal activity of crude aqueous extracts of *A. senegal* and *A. tortilis* was evaluated against three fungal strains (*H. rostratum, F. solani,* and *A. alternata*) by poisoned food technique [30]. To 9 cm petri plate, 1 mL of the extract was added followed by 19 mL of molten potato dextrose agar and mixed gently by swirling. The modified agar was allowed to solidify, after which a mycelial plug (6 mm) was placed in the center of the plate. The mycelial plug was removed from the periphery of 9 days old actively growing colony. The above–mentioned experiments was carried out aseptically in a laminar air flow. After inoculation, petri plates were incubated at 25± 2^0C for 7days. All fungal strains were subjected to different concentrations of aqueous extracts in triplicates. Results were noted by measuring the diameter of mycelial growth when the control plate showed full plate growth and percentage growth inhibition was calculated as follows:

% inhibition= (AC− AT)/AC × 100

Where AC = colony diameter in control plate,

AT = diameter of the colony in treatment plate

2.5 Scanning Electron Microscopy

Scanning electron microscopy (SEM) was employed to analyze the mycelia treated with crude aqueous extract and was compared with the untreated control. In brief, small agar pieces (6 mm) were aseptically cut out from the inhibition zone and were fixed in 2.5% (v/v) glutaraldehyde buffered with 0.1 M sodium phosphate buffer (pH 7.4). The suspension was centrifuged after 48 h, rinsed thrice with phosphate-buffered saline, and was dehydrated in graded ethanol series (60 % - 100 %). The dehydrated specimen were freeze-dried and were mounted onto stubs using double-sided carbon type, and then were coated with a thin layer of gold. The processed specimens were investigated under a scanning electron microscope (JSM–6060LV–JEOL, Japan–LTD).

2.6 Fourier Transform Infrared Spectrometry Analysis

Aqueous extracts with strongest antifungal activity were qualitatively analyzed by Fourier Transform Infrared Spectrometry Analysis (FTIR) spectrometer for the detection and confirmation of functional constituents in plant extracts. The aqueous extracts of *A. senegal*

and *A. tortilis* were passed into the FTIR and functional groups of the components were separated based on its peak ratio. A sophisticated computer-controlled spectrophotometer (Nicolet–6700, Thermo Scientific, USA) equipped with a beam splitter, a detector (DTGS) and OMNIC software was used to generate the FTIR spectra in the mid-region of 500 - 4000 cm^{-1}. The IR spectrums obtained from the analysis were used to interpret the functional groups present in each of the aqueous extracts.

2.7 Statistical Analysis

All the experiments were performed in triplicate. Data are reported as means and standard deviations (SD). One-way analysis of variance (ANOVA) was used for data analysis and the significant differences ($p<0.05$) between the means were performed.

3. RESULTS

3.1 Antifungal activity

The antifungal activity exhibited by aqueous extracts of *A. senegal* and *A. tortilis* is summarized in Table 1. The aqueous extract of *A. senegal* at 1%, 2.5%, and 5% concentrations did not inhibit the growth of *A. alternata* (Table 1).

Table 1. Antifungal activity of different concentrations of aqueous extracts of *Acacia senegal* and *Acacia tortilis* and the percentage mycelial inhibition

	Alternaria alternata		***Helminthosporium rostratum***		***Fusarium solani***	
Acacia senegal	Growth (mm)	Inhibition %	Growth (mm)	Inhibition %	Growth (mm)	Inhibition %
Control	8.0 (0.00)	0.0	8.0 (0.00)	0.0	8.0 (0.00)	0.0
1.0%	8.0 (0.00)	0.0	8.0 (0.00)	0.0	7.4 (0.13)	1.5
2.5%	8.0 (0.00)	0.0	7.5 (0.06)	5.9	7.7 (0.23)	4.1
5.0%	8.0 (0.00)	0.0	7.4 (0.13)	7.3	7.9 (0.20)	7.9
Acacia tortilis						
Control	8.0 (0.00)	0.0	8.0 (0.00)	0.0	8.0 (0.00)	0.0
1.0%	8.0 (0.00)	0.0	8.0 (0.00)	0.0	7.3 (0.26)	8.8
2.5%	8.0 (0.00)	0.0	7.6 (0.08)	5.3	6.5 (0.43)	18.5
5.0%	4.2 (0.21)	47.9	4.5 (0.00)	43.8	6.5 (0.23)	19.4

*Values are presented as means (SD) of triplicates.

The fungal growth in the treated plates was comparable to the growth observed in the control plate (Figure 1a). While the aqueous extract of *A. senegal* at 1% concentration showed no effect on the growth of *H. rostratum*, it exhibited very mild activity on the mycelial

growth at 2.5% and 5% concentrations (Table 1). There was no difference observed in the confluence of fungal growth in the control plate and those treated at 1% concentration, the plates treated with 2.5% and 5% concentrations showed very weak inhibitory activity (Figure 1b). The aqueous extract of *A. senegal* showed very mild inhibitory activity against *F. solani* which increased as the concentration increased from 1% to 5% concentration (Table 1). The diameter of growth observed across the treated plates (1%, 2.5%, and 5%) and control plates was similar (Figure 1c).

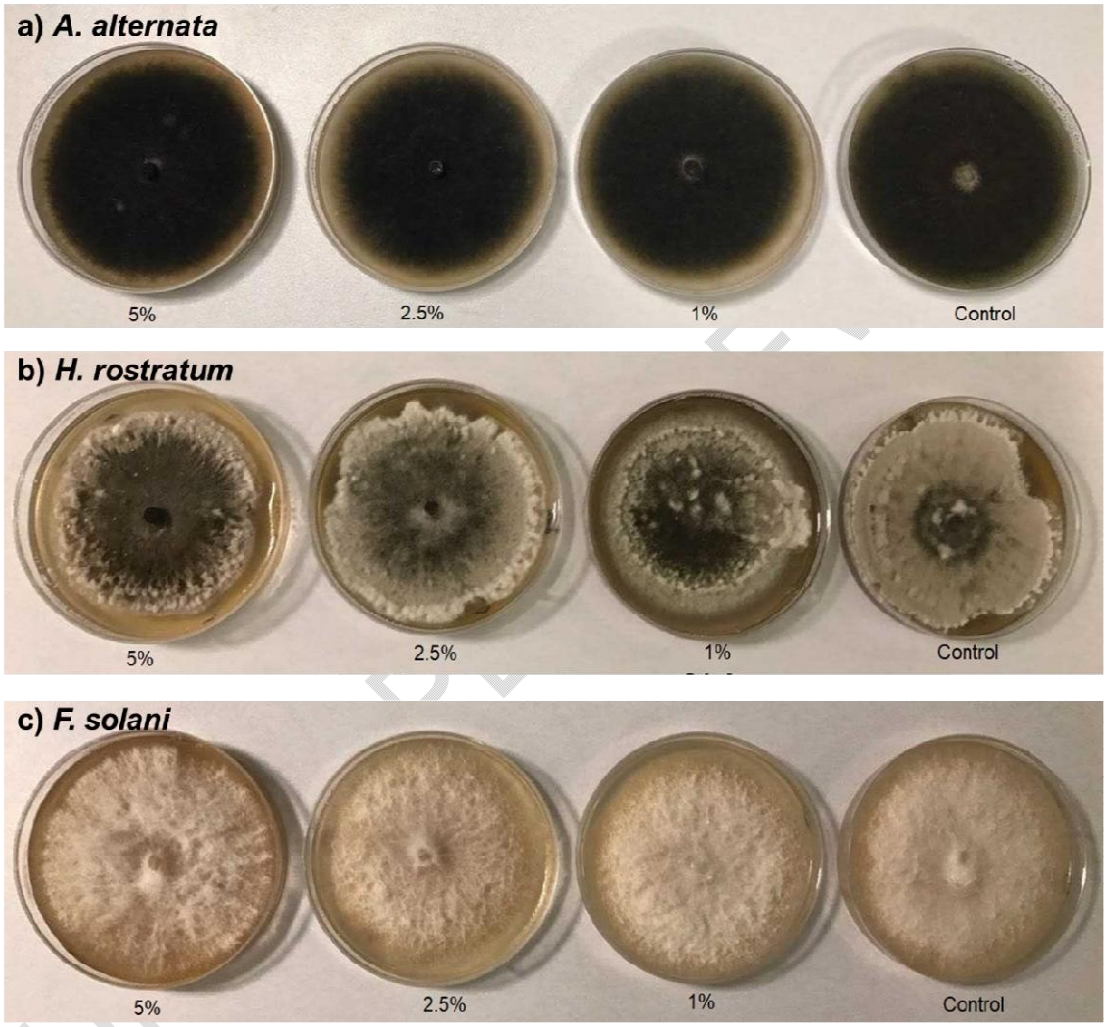


Figure 1: *In vitro* activity of aqueous extract of *Acacia senegal* on three phytopathogenic fungi; a) *A. alternata,* **b)** *H. rostratum and* **c)** *F. solani*

The aqueous extract of *A. tortilis* did not inhibit the growth of *A. alternata* at 1% and 2.5% concentrations. However, it induced moderate inhibition of fungal colonies at 5% and *H. rostratum* (Table 1). The confluence of fungal growth was comparable in the control, 1%, and 2.5% treated plates, whereas it showed a clear zone of inhibition at 5% concentration (Figure 2a). Similarly, the extract of *A. tortilis* showed no activity and minimal activity at 1% and 2.5% concentrations but it showed a moderate activity at 5% concentration (Table 1 and Figure 2b). The aqueous extract of *A. tortilis* showed mild potency against *F. solani* which increased as the concentration increased. The growth in the control and 1% treated plates

was comparable, while those treated with 2.5% and 5% clearly showed clear zones of inhibitions (Figure 2c).

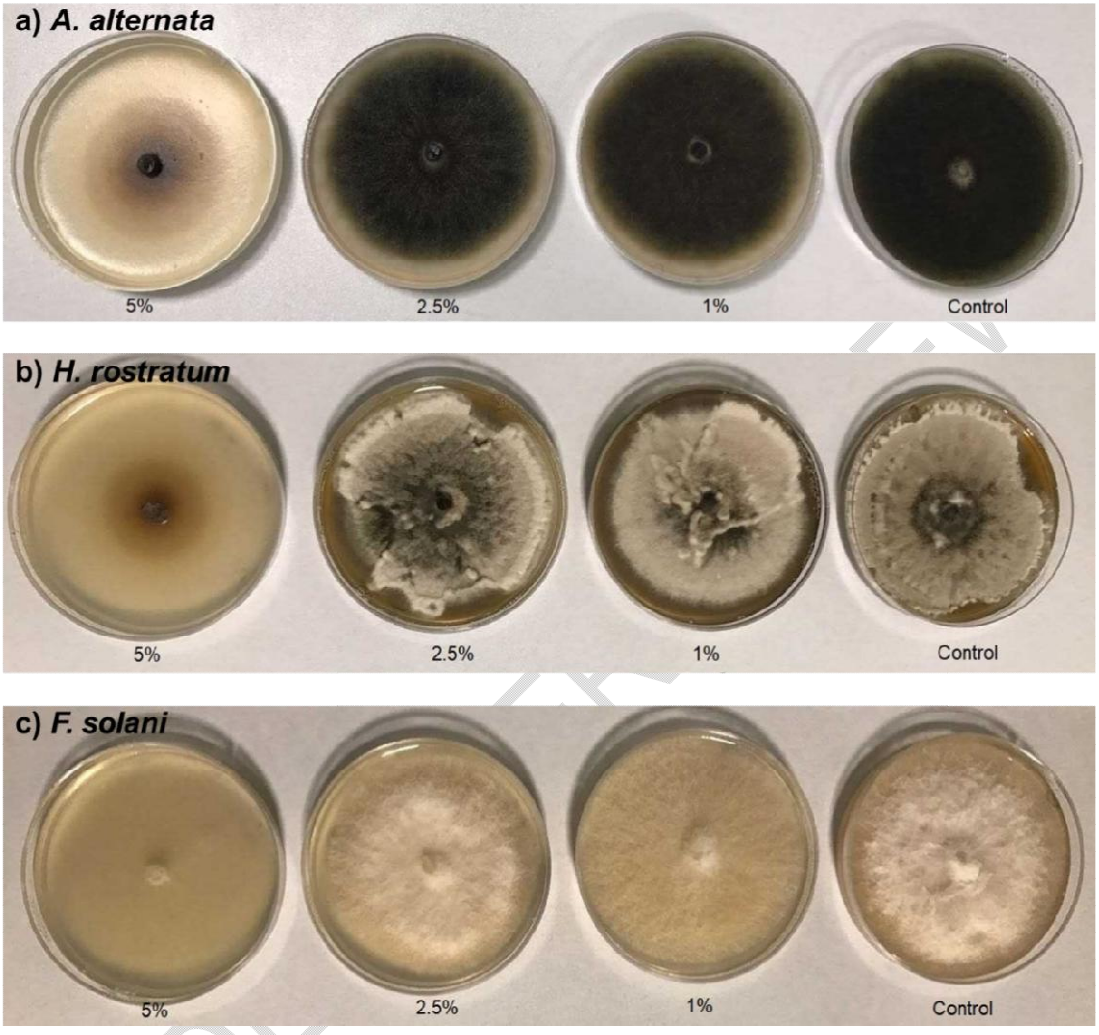


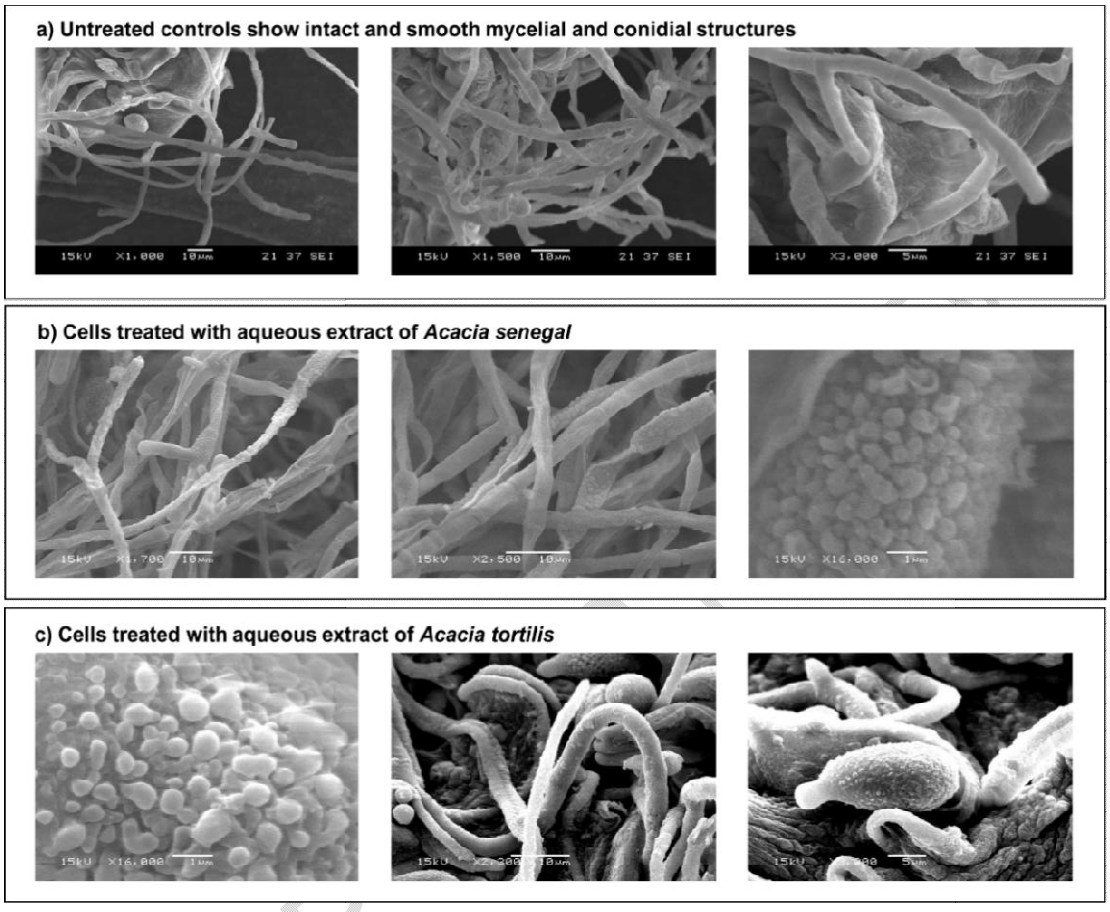
Figure 2: *In vitro* activity of aqueous extract of *Acacia tortilis* on three phytopathogenic fungi; a) *A. alternata*, **b)** *H. rostratum and* **c)** *F. solani*

3.2 Scanning electron microscopy

The scanning electron micrographs of untreated mycelia (controls) of *A. alternata* along with the plates treated with aqueous extracts of *A. senegal* and *A. tortilis* with the maximum inhibitory effect of *A. tortilis* were selected for assessing the morphological changes.

The untreated-biomass (control) of *A. alternata* had normal tubular hyphae and intact mycelial and conidial growth and absence of structural changes (Figure 3a). The SEM images of *A. alternata* treated with aqueous extract of *A. senegal* showed smooth external surface with no morphological changes (Figure 3b). However, plates treated with aqueous extract of *A. tortilis* showed deformation of cellular structure as indicated by shrunken curly

183 hyphae of variable sizes, deformed and wrinkled external surfaces, and compressed conidia
184 (Figure 3c).
185



186

187 **Figure 3: Scanning electron microphotographs of *Alternaria alternata***; **a)** Untreated
188 controls show intact and smooth mycelial and conidial structures, **b)** Cells treated with
189 aqueous extract of *Acacia senegal*, and **c)** Cells treated with aqueous extract of *Acacia*
190 *tortilis*

191 **3.3 Fourier-transform infrared spectroscopic analysis of the aqueous extracts**

192 Aqueous extracts of both *A. senegal* and *A. tortilis* were subjected to FTIR analysis to
193 identify the functional groups of the active components present in extract based on the peak
194 values in the region of IR radiation. In *A. senegal*, IR spectrum showed strong absorption
195 peaks at 3437, 2930, 2143, 1634, 1433, 1153 and 1172, 574, and 439 cm-1 which
196 corresponds to alcohols, carboxylic acids, alkynes, amides, alkanes, alkyl amines, halogen,
197 and cycloalkanes groups, respectively (Figure 4a). For *A. tortilis*, broad peaks were recorded
198 at 2930, 2367 and 2340, 2121, 1621, 1429, 1081 and 1032, and 574 cm^{-1} that corresponds
199 to CH asymmetry, phosphine, alkyne, conjugated alkene, carboxylic acid, alkyl halides, and
200 nitriles functional groups, respectively (Figure 4b).

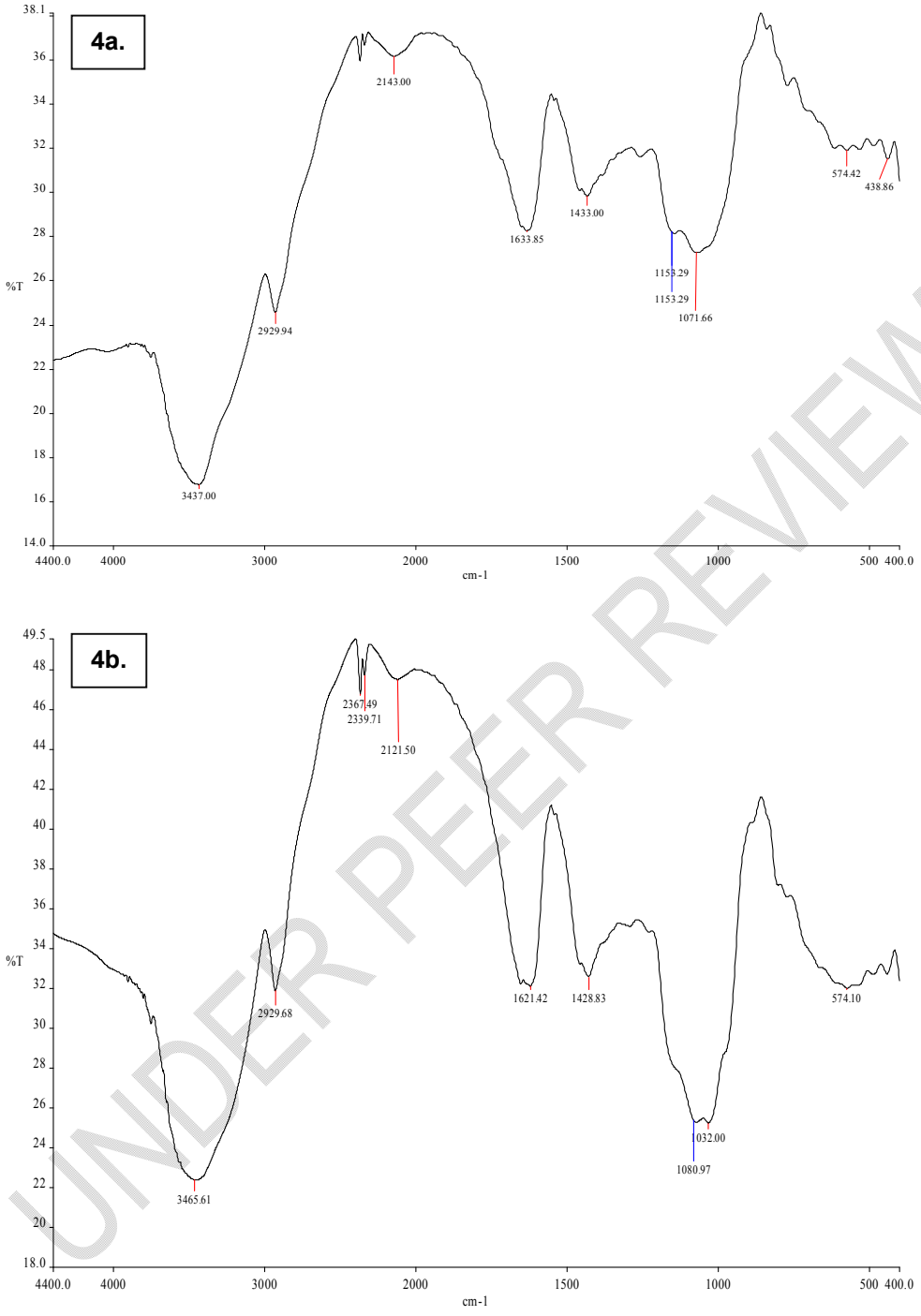


Figure 4: Fourier Transform Infrared spectrum of the aqueous extract of *Acacia* species; **a)** FTIR spectrum of the aqueous extract of *Acacia senegal,* and **b)** FTIR spectrum of the aqueous extract of *Acacia tortilis*.

4. DISCUSSION

Plant diseases caused due to fungiform impose significant damage to many economic crops worldwide. Synthetic fungicides are the first-line defense for protecting the plants against fungal infections. However, commercially available fungicidal agents are toxic and produce undesirable effects on other organisms, soil, plants, and water [41]. Moreover, the development of resistance of pathogenic fungi towards the synthetic fungicides has been a matter of great concern. Plant-derived antifungal agents represent a vast untapped source with tremendous potential.

The present study assessed the antifungal activity of crude aqueous extracts of *A. senegal* and *A. tortilis* against three phytopathogenic fungal strains viz., *A. alternata, H. rostratum*, and *F. solani*. Results from this study showed that aqueous extracts of *A. senegal* and *A. tortilis* varied in their effectiveness in inhibiting fungal growth. While SEM microphotographs confirmed the presence of ultrastructural changes in the treated cells, FTIR spectroscopy showed the presence of important functional groups responsible for antifungal activity.

The arid and semi-arid regions of the Middle East is a rich source of many medicinal plants [1]. Gum acacia is one of the most important medicinal plants available in the entire region. It contains various primary and secondary metabolic constituents (alkaloids, catechins, chalcones, flavones, flavonoids, polyphenols, and tannins) which have been traditionally used for the treatment of various plant and human diseases [15]. Two different species of gum acacia (*A. senegal* and *A. tortilis*) selected based on their traditional use [42]. Three different concentrations (1%, 2.5%, and 5%) of the aqueous extracts of both plants were screened for their in vitro activity against three important pathogenic plant fungi (*A. alternaria*, *H. rostratum*, and *F. solani*). The extract of *A. senegal* showed no effect on the growth of *A. alternaria* at all the three concentrations tested (1%, 2.5%, and 5%) whereas, it showed very mild activity on *H. rostratum* and *F. solani* at 2.5% and 5% concentrations. Aqueous extract of *A. tortilis* exhibited moderate activity against *A. alternata* at 5% concentration, and mild to moderate activity against H. rostratum and *F. solani*. Although both Acacia species showed antifungal activity, the aqueous extract of *A. tortilis* showed relatively higher potency in inhibiting the mycelial growth of all the three tested fungal strains. Limited effectiveness of aqueous extract of *A. senegal* against *A. alternaria* and the least activity against *H. rostratum* and *F. solani* could be partially due to incomplete extraction of the active principles [31]. Other factors include solubility, pH, volatility, diffusion characteristics in the growth medium, and fungal strains [32, 33].

Furthermore, SEM and FTIR studies were conducted to characterize the ultrastructural changes in the mycelia and identify the functional groups in the plant extracts respectively. SEM studies of the cells treated with aqueous extract of *A. tortilis* showed a deleterious effect on mycelial and conidial structures. Results from the FTIR analysis revealed the presence of several functional groups (alcohols, carboxylic acids, alkynes, amides, alkanes, alkyl amines, halogen, and cycloalkanes groups) that can act alone or in synergy, as demonstrated by other studies [5, 34-36]. As this is the first study to investigate the antifungal activity of crude aqueous extracts of *A. senegal* and *A. tortilis* against *A. alternaria, H. rostratum* and *F. solani*, formal comparison of the data obtained in this study is not possible. However, the results of antifungal activity of the *Acacia* species assessed in this study are similar to those reported in previous studies [16, 37]. In the study by Baig et al. aqueous extracts of *A. nilotica* was found to exhibit moderate activity against *Aspergillus flavus* and *Aspergillus niger*. The antifungal activity increased as the concentration increased from 10% to 25% [37]. Similarly, in a study by Al-Huqail et al. the aqueous extract of *A. saligna* (Labill) inhibited the growth of *Penicillium chrysogenum*. Furthermore, the percentage inhibition of the fungal mycelium increased as the extract concentration

increased [16]. The antifungal activity exhibited by both *A. senegal* and *A. tortilis* may be attributed to the presence of numerous phytoconstituents such as polyphenols, and flavonoid compounds which are reported to be abundantly present among *Acacia* species [16, 38-40].

5. CONCLUSION

The results from this study provide evidence that the aqueous extracts of *A. senegal* and *A. tortilis* varied in their efficacy in inhibiting the mycelial growth of tested fungal species. Although the selected concentration of aqueous extracts was unable to completely inhibit the selected phytopathogens, they can potentially be explored alone or in combination as a source of natural fungicidal material. The high proportion of active extracts in the *Acacia* species corroborates the validity of the use of these plant species as natural-plant derived fungicides. Further, large-scale *in vitro* and *in vivo* studies are warranted to replicate the findings of this study.

COMPETING INTERESTS

The author declare no conflict of interests.

REFERENCES

1. FAO conservation guides, Part four: Selected species of *Acacia*. Accessible at: http://www.fao.org/3/V5360E/v5360e0b.htm (accessed September 2019) 2019.
2. Bui EN, Thornhill A, Miller JT. Salt- and alkaline-tolerance are linked in *Acacia*. Biol Lett 2014;10:20140278.
3. Salima K, Lutts S, Fatiha A. Effect of drought stress on the photosynthesis of *Acacia tortilis* subsp. *raddiana* at the young seedling stage. Photosynthetica 2015;53.
4. Lal Saini M, Saini R, Roy S, Kumar A. Comparative pharmacognostical and antimicrobial studies of *Acacia* species (Mimoceae). J Med Plants Res 2008;12.
5. Daoub RMA, Elmubarak AH, Misran M, Hassan EA, Osman ME. Characterization and functional properties of some natural *Acacia* gums. J Saudi Soc Agric Sci 2018;17:241-9.
6. Williams PA, Phillips GO. 11 - Gum Arabic. In: G. O. Phillips and P. A. Williams editors. Handbook of hydrocolloids (Second Edition): Woodhead Publishing; 2009. p. 252-73.
7. Alawi SMA, Hossain MA, Abusham AA. Antimicrobial and cytotoxic comparative study of different extracts of Omani and Sudanese Gum acacia. Beni-Suef Univ J Basic Appl Sci 2018;7:22-6.
8. Elegami AA, Almagboul AZ, Omer ME, El Tohami MS. Sudanese plants used in folkloric medicine: screening for antibacterial activity. Part X. Fitoterapia 2001;72:810-7.
9. Dietetics and Nutrition. What role can *Acacia* gum play in the food industry today? Accessible at: https://www.allandetrobert.com/wp-content/uploads/2017/07/INFO_The-role-of-Gum-Acacia-in-the-food-industry-Technical-paper-ENG-BD-1.pdf (accessed September 2019), 2013.
10. FAO/WHO. Compendium of food additives. Food and Nutrition Paper 52 Addendum 7, Rome.1999.

11. El-Atta H, Aref I, A. Khalil S. Increased gum Arabic production after infestation of *Acacia senegal* with *Aspergillus flavus* and *Pseudomonas pseudoalcaligenes* transmitted by *Agrilus nubeculosus*. Biotechnol 2011;10:159-66.
12. Salih S, Sabir O, Mshelbwala M, Gadour M. Gum Arabic a superb anti-diarrheal agent. Sudan J Med Sci 2012;7:83-8.
13. Negi BS, Dave BP. *In vitro* antimicrobial activity of *Acacia catechu* and its phytochemical analysis. Indian J Microbiol 2010;50:369-74.
14. Duke J. Handbook of legumes of world economic importance; 2012.
15. Duke JA, Wain KK. Medicinal plants of the world. Computer index with more than 85,000 entries1981. p. 46–52.
16. Al-Huqail AA, Behiry SI, Salem MZM, Ali HM, Siddiqui MH, Salem AZM. Antifungal, antibacterial, and antioxidant activities of *Acacia saligna* (Labill.) H. L. Wendl. Flower extract: HPLC analysis of phenolic and flavonoid compounds. Molecules 2019;24:700.
17. Khan AJ, Zouba AA, Seapy DG. Antifungal activity from leaves of *Acacia nilotica* against *Pythium aphanidermatum*. Agri Sci 1996;1.
18. Khoshkholgh-Pahlaviani MRM, Massiha AR, Issazadeh K, Bidarigh S, Giahi M, Ramtin M. Evaluation of antifungal activity of methanol extract of *Acacia* (*Anagalis arvensis*) leaves and nystatin against *Candida albicans in vitro*. Zahedan J Res Med Sci 2013;15:39-41.
19. Rai SA, Prasad MS, Singh K. Evaluation of the antifungal activity of the potent fraction of hexane extract obtained from the bark of *Acacia nilotica*. IJSR 2014;3:730-8.
20. Thendral T, Lakshmi T. Antifungal activity of *Acacia catechu* bark extract against dermatophytes: An *in vitro* study. J Adv Pharm Edu Res 2017;7:25-7.
21. Chung KR. Stress response and pathogenicity of the necrotrophic fungal pathogen *Alternaria alternata*. Scientifica 2012;2012:635431.
22. Laemmlen F. *Alternaria* diseases. In: University of California editor. Agriculture and Natural Resources 2001.
23. Mangnalikar SS, Gawai DU. Effect of herbal extract on growth of *Alternaria alternata*. Int J Recent Trends Sci Technol 2018:43-5.
24. Imrani N, Boudoudou H, Mouria A, Touati J, Touhami OA, Benkirane R et al. Pathogenicity of *Helminthosporium rostrata* on rice varieties widely grown in Morocco. IJEAB 2017;2:1003-6.
25. Luginbuhl S. *Fusarium solani*: A class project for PP728 soil borne plant pathogens, Fall 2010 2010.
26. Vijayasanthi M, Kannan V, Venkataswamy R, Doss A. Evaluation of the antibacterial potential of various solvent extracts of *Acacia nilotica linn*. Leaves. Hygeia J D Med 2012;4.
27. Otto RBD, Ameso S, Onegi B. Assessment of antibacterial activity of crude leaf and root extracts of *Cassia alata* against *Neisseria gonorrhea*. Afr Health Sci 2014;14:840-8.
28. Singh B, Dubey S, Siddiqui M. Antimicrobial activity of natural edible gums. World J Pharm Sci 2015;3:2217-21.
29. Hu Q, Gerhard H, Upadhyaya I, Venkitanarayanan K, Luo Y. Antimicrobial eugenol nanoemulsion prepared by gum Arabic and lecithin and evaluation of drying technologies. Int J Biol Macromol 2016;87:130-40.
30. Grover R, Moore J. Toxicometric studies of fungicides against brown rot organisms *Sclerotinia fructicola* and *S. laxa*. Phytopathol 1962;52:876- 80.

31. El-Mahmood AM, Hamuel JD, Ladan N. Antimicrobial screening of stem bark extracts of *Vitellaria paradoxa* against some enteric pathogenic microorganisms. Afr J Pharm 2008;2:89-94.
32. Gillitzer P, Martin AC, Kantar M, Kauppi K, Dahlberg S , Lis D. Optimization of screening of native and naturalized plants from Minnesota for antimicrobial activity. J Med Plants Res 2012;6:938-49.
33. Mohammed AME. Estimation of active components in gum Arabic collected from western Sudan. Int J Sci Res 2015;6(3):ART20171695.
34. Diaz Dellavalle P, Cabrera A, Alem D, Larrañaga Luz P, Ferreira F, Rizza MD. Antifungal activity of medicinal plant extracts against phytopathogenic fungus *Alternaria spp.* Chil J Agric Res 2011;71:231-9.
35. Suleiman IY. Phytochemical and spectroanalytical characterizations of some plants extract as green corrosion inhibitors. J Materials Environ Sci 2017;8:3423-32.
36. Udo I, Odoemelam SA, Eddy NO. Physicochemical and FTIR studies on *Acacia senegal* and *Anacardium occidentale* blends. J Ind Environ Chem 2017;1:31-5.
37. Baig M, Fatima S. Antifungal activity of plant extracts against some storage seed borne fungi of sunflower. J Med Chem Drug Disc 2017;2:141-6.
38. Alajmi MF, Alam P, Alqasoumi SI, Ali Siddiqui N, Basudan OA, Hussain A et al. Comparative anticancer and antimicrobial activity of aerial parts of *Acacia salicina*, *Acacia laeta*, *Acacia hamulosa* and *Acacia tortilis* grown in Saudi Arabia. Saudi Pharm J 2017;25:1248-52.
39. Daoub RMA, Elmubarak AH, Misran M, Hassan EA, Osman ME. Characterization and functional properties of some natural *Acacia* gums. J Saudi Soc Agric Sci 2018;17:241-9.
40. Lopez Torrez L, Nigen M, Williams P, Doco T, Sanchez C. *Acacia senegal* vs. *Acacia seyal* gums - Part 1: Composition and structure of hyperbranched plant exudates. Food Hydrocolloids 2015;51.
41. Shuping DSS, Eloff JN. The use of plants to protect plants and food against fungal pathogens: a review. Afr J Tradit Complement Altern Med 2017;14:120-17.
42. Wekesa C, Makenzi PM, Chikamai BN, Luvanda AM, Muga MO. Traditional ecological knowledge associated with *Acacia senegal* (Gum Arabic tree) management and gum Arabic production in northern Kenya. Int Forest Rev 2010;12:240-6.