Original article

Natural products of *Alternaria* sp., an endophytic fungus isolated from *Salvadora persica* from Saudi Arabia

Abdallah M. Elgorban a,b,c, Ali H. Bahkali a,c, Dunia A. Al Farraj a, Mohamed A. Abdel-Wahab a

a Department of Botany and Microbiology, College of Science, King Saud University, P.O. Box: 2455, Riyadh 1145, Saudi Arabia
b Center of Excellence in Biotechnology Research, King Saud University, P.O. Box: 2455, Riyadh 1145, Saudi Arabia
c Plant Pathology Research Institute, Agricultural Research Center, Giza, Egypt

**Article history:**
Received 28 January 2018
Revised 26 March 2018
Accepted 8 April 2018
Available online 18 April 2018

**Keywords:**
Arabian Peninsula
Antibacterial
Pleosporaceae
Molecular phylogeny

**Abstract**
This study is to evaluate the potential of endophytic fungi of *Salvadora persica* for the production of bioactive compounds against pathogenic bacteria and fungi. Forty-two fungal isolates were obtained from 135 young and old stem and 125 root segments. Those 42 isolates representing ten fungi include: *Trichoderma* sp. (the most common), two species of *Alternaria*, *Rhizopus arrhizus* and 6 sterile mycelia. The ten fungi were grown in liquid culture and their crude extracts were tested against pathogenic bacteria and fungi. Nine crude extracts gave positive reactions against pathogenic bacteria of which *Alternaria* sp. (A8) was chosen further study. The fungal isolate was growing as sterile mycelium and was identified by phylogenetic analyses based on LSU rDNA sequence data and it might represent undescribed species of *Alternaria*. Sixty-two bioactive chemical compounds were identified from the ethyl acetate crude extracts of *Alternaria* sp., of which the following were recorded as major compounds in the active sub-fractions.

© 2018 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

There is a general call for new antibiotics, chemotherapy agents, and agrochemicals that are highly effective, possess low toxicity, and have minor environmental impact (Patil et al., 2015). Due to an increasing realization of the health hazards and toxicity associated with the indiscriminate use of synthetic drugs and antibiotics, interest in the use of biogenic drugs has been renewed around the world (Nalawade et al., 2003). During the last twenty years, more than half of the drugs in the market come from biological resources (Vuorela, 2004). Medicinal plants and their endophytes have proved to be a good source of bioactive metabolites (Cai et al., 2004, Newman and Cragg, 2007). Around 420,000 plant species exist in nature (Vuorela, 2004). Medicinal plants have been used to prevent or cure illness due to the presence of bioactive compounds in their tissues and were used in traditional medicines for several millennia (Radad et al., 2006; Jahanpour et al., 2015) (see Fig. 1).

Endophytes are microorganisms that reside in the healthy looking plant tissues and are a promising source of novel bioactive natural metabolites (Sun and Guo, 2012; Patil et al., 2016). Carroll (1986) defined endophytes as mutualists that colonize aerial parts of living plant tissues and do not cause disease symptoms. Petrini (1991) defined endophytes as organisms that colonize internal plant tissues for some time in their life without causing apparent harm to the host. Endophytes are present in every plant on earth including: mosses (Davey and Currah, 2006), ferns (Swatzell et al., 1996), grasses (Su et al., 2010), shrubs (Jannone et al., 2015), deciduous and coniferous trees (Albrechtsen et al., 2010; Sun et al., 2011), and even lichens (Li et al., 2007a,b).

Endophytic fungi mainly Ascomycetes and their asexual stages, while Basidiomycota, Zygomycota and Chytridiomycota are poorly represented (Sinclair and Cerkauskas, 1996). Endophytes can produce various bioactive natural products (Aly et al., 2010; Liu et al., 2011) that promote host growth and resistance to environmental stress (Saikkonen et al., 2010), decompose litter (Purahong and Hyde, 2011; Sun et al., 2011), suppress pathogens, aid in removing contaminants, solubilize phosphate or contribute to nitrogen assimilation for plants (Hallmann et al., 2006).

Medicinal plants produce bioactive compounds capable of preventing or curing illnesses. They also provide a unique...
environment for endophytes and have been recognized as a repository of endophytes with novel metabolites of pharmaceutical importance (Wiyakrutta et al., 2004). Endophytes affect the quality and quantity of the crude drugs derived from medicinal plants through a particular fungus-host interaction (Jia et al., 2016). Examples include an anticancer agent isolated from an endophytic taxon growing on the leaves of the Indian medicinal plant Mimosa elengi (Deshmukh et al., 2009) and the potent anticancer compound secalonic acid D, which was isolated from a mangrove endophytic fungus and displays high cytoxicity to HL60 and K562 cells by inducing leukemia cell apoptosis (Zhang et al., 2009).

Fungal endophytes colonize internal healthy plant tissues and persist without causing visible disease symptoms (Hyde and Soytong, 2008; Purahong and Hyde, 2011). They have been isolated from nearly all studied hosts, including Populus tremula (Albrechtsen et al., 2010), Pinus halepensis (Botella et al., 2010), grasses (Su et al., 2010; Ghimire et al., 2011), Taxus globosa (Rivera-Orduna et al., 2011), Vitis vinifera (Gonzalez and Tello, 2011) and sea grasses (Sakayaroj et al., 2010). Some endophytic fungi are known to produce bioactive metabolites (Xu et al., 2010), and these metabolites may be similar to those produced by the host (Keller et al., 2005). For example, a paclitaxol-producing endophyte, Taxomyces andreanae, was successfully discovered from the Pacific yew Taxus brevifolia (Stierle et al., 1993). A recent study using a paclitaxel-producing endophytic isolate of Chaetomium sp. reported a potential industrial yield of 1124.34 g/L using an optimized fermentation process (Jin et al., 2011). A gibberellin-producing endophytic strain of Penicillium commune has also been isolated from Sesamum indicum (Choi et al., 2005).

Kingdom of Saudi Arabia is gifted with a wide range of flora, consisting of a large number of medicinal herbs, shrubs and trees (Mossa et al., 2000). It is estimated that the flora of Saudi Arabia has a great medicinal species diversity, which is expected to be more than 1200 (over 50%) out of its 2287 species (Rahman et al., 2004). Endophytic fungi were isolated from a few species of medicinal plants in Saudi Arabia (Gashgari et al., 2016). This study aims to isolate and characterize bioactive natural products from endophytic fungi of Salvadora persica collected from Okair Geological Reserve, Dammam city, Saudi Arabia.

Salvadora L. (Salvadoraceae) is evergreen trees or shrubs distributed in tropical Africa and Asia (Arora et al., 2014). Species of Salvadora are deep rooted mesomorphic xerophytes with high salt tolerance (Khan and Qaiser, 2006). Salvadoraceae is a small family comprising of three genera (Azima Lam., Dobera and Salvadora) and 12 species which are distributed mainly in the tropical and sub-tropical Asia and Africa (Willis, 1973). Salvadoraceae in Saudi Arabia is represented by two genera and two species namely: Dobera glabra (Forssk.) Juss. Ex Poir and S. persica L. (Arak) has antiurolithiatic properties (Geetha et al., 2010). Due to the presence of benzyl isothiocynate S. persica is widely used in an oral hygiene as tooth-cleaning stick (miswak) (Halawany, 2012). Although it is a pre-Islamic practice, the use of miswak has dramatically increased after the spread of Islamic culture (Bos, 1993). There are 182 plant species suitable for preparing tooth brush sticks, however, miswak harvested from S. persica are the most commonly used in different parts of the world (Mohamed et al., 2006). The use of the tooth-cleaning sticks dates back to the Babylonians some 7000 years ago. They were also used by the Greeks, Romans, Jews and the Egyptians.

A few studies have been carried out to study endophytic fungi of S. persica (Korejo et al., 2014). Korejo et al., (2014) isolated 5 endophytic fungi from S. persica. These fungi namely: Aspegillus niger, A. flavus, Macrophomina phaseolina, Penicillium restrictum and P. canescens. Dhankhar et al. (2013a) isolated seventeen endophytic fungi from Salvadora oleoides Decne in India and studied their abilities to produce natural products. Isolated endophytic fungi include: 10 Aspergillus spp., Cladosporium herbarum, Epicoccum nigrum, Fusarium moniliforme, Penicillium chrysogenum, Phoma sp. and Pythium spinosum. In another study, Dhankhar et al. (2013b) isolated 27 fungal species representing 18 fungal genera from 3750 samples of leaf segment, petiole and stem from five different sites of three seasons were collected and analyzed. In the current study we isolate endophytes from S. persica, to investigate endophyte extracts for anti-bacterial activity using human pathogenic...
Fig. 3. Phylogenetic relationship of *Rhizopus arrhizus* (A9) along with phylogenetically related fungi in the genus *Rhizopus* based on the nucleotide sequences of LSU rDNA. The maximum likelihood tree (ML) was constructed in MEGA7 (Tamura et al., 2013). Bootstrap support on the nodes represent ML and MP ≥ 50% respectively. The tree is rooted to *Rhizomucor miehei*. Newly generated sequence in the present study is in blue.

Fig. 4. Phylogenetic relationship of *Aspergillus* sp. (A3) along with phylogenetically related fungi in the genus *Aspergillus* based on the nucleotide sequences of LSU rDNA. The maximum likelihood tree (ML) was constructed in MEGA7 (Tamura et al., 2013). Bootstrap support on the nodes represent ML and MP ≥ 50% respectively. The tree is rooted to *Penicillium steckii*. Newly generated sequence in the present study is in blue.

**Table 1**

Endophytic fungi isolated from 135 stem segments and 125 root segments *Salvadora Persica*.

| Fungi                  | Organ | N   | %   |
|------------------------|-------|-----|-----|
| *Alternaria* sp.1 (A4) | stem  | 2   | 1.5 |
| *Alternaria* sp.2 (A8) | stem  | 3   | 2.2 |
| *Rhizopus arrhizus* A. Fisch. (A9) | root  | 7   | 5.6 |
| *Aspergillus* sp. (A3) | stem  | 5   | 1.7 |
| *Trichoderma* sp. (A9) | stem  | 3   | 2.2 |
| Sterile mycelium (A2)  | stem  | 4   | 3.7 |
| Sterile mycelium (A5)  | stem  | 3   | 2.2 |
| Sterile mycelium (A6)  | stem  | 1   | 0.7 |
| Sterile mycelium (A7)  | stem  | 4   | 3.7 |
| Sterile mycelium (A10) | root  | 6   | 4.8 |

N number of isolates. % Frequency of occurrence. # Supported by molecular data.
Table 3
Major natural products compounds identified in the ethyl acetate extract from the culture filtrate of Alternaria sp. (A8) by GC-MS:

| Peak no. | R-Time | Name of the compound | Molecular formula | Molecular weight | Area % | Activity |
|----------|--------|----------------------|-------------------|------------------|--------|----------|
| 40       | 40.92  | 1,2-Benzenedicarboxylic acid, bis (2- ethylhexyl) ester | C_{24}H_{38}O_{4} | 390              | 51.15  | Antimicrobial |
| 10       | 20.42  | 6,8-Dimethoxy-4-methyl-4H-chromene | C_{10}H_{12}O_{4} | 232              | 10.87  | Antioxidants |
| 20       | 29.101 | 2,5-Cyclohexadien-1-one, 2,6-bis (1,1-dimethylethy)-4-ethyliden- | | | 3.94 | Antimicrobial, antioxidant, plasticizer, cosmetics |
| 11       | 21.893 | Cetene | C_{16}H_{32} | 224.43 | 3.32 | Antioxidants |
| 22       | 29.817 | 1,2-Benzenedicarboxylic acid, dibutyl ester (CAS) Butyl phthalate | C_{16}H_{22}O_{4} | 278 | 3.23 | Antimicrobial, antioxidant, plasticizer, cosmetics |
| 16       | 26.242 | 1-Octadecene | C_{18}H_{36} | 252.48 | 2.64 | Anticancer, antioxidant and antimicrobial activities |
| 4        | 9.87   | Benzeneethanol | C_{6}H_{10}O | 122.16 | 2.47 | |
| 27       | 31.971 | 1-Octadecene | C_{18}H_{36} | 252.48 | 2.21 | |
| 23       | 30.201 | Cycloexanes | C_{28}H_{40} | 388.60 | 1.96 | |
| 2        | 4.03   | 1-Butanol, 3-methyl-acetate | C_{6}H_{12}O_{2} | 130.18 | 1.91 | |
| 8        | 16.991 | 1-Tetradecene | C_{16}H_{32} | 196.37 | 1.77 | Antimicrobial |
| 5        | 11.559 | Naphthalene | C_{10}H_{8} | 128.17 | 1.69 | Insecticidal |
| 13       | 24.001 | Phenol, 2,4-di-t-butyl-6-nitro | C_{14}H_{21}NO_{3} | 251.32 | 1.59 | Antimicrobial, anticancer |

Table 2
Bioassay results of endophytic fungi of S. persica (the numbers are the clear zones in centimeter).

| Fungi                  | S. aureus | E. coli | C. albicans | A. fumigatus |
|------------------------|-----------|---------|-------------|-------------|
| Alternaria sp.1 (A4)   | 0.9       | 0.9     | Negative    | Negative    |
| # Alternaria sp.2 (A8) | 1.3       | 1.2     | Negative    | Negative    |
| # Rhizopus arrhizus (A9)| 1.7       | 2.3     | Negative    | Negative    |
| Trichoderma sp. (A1)   | 0.8       | 1.1     | Negative    | Negative    |
| # Aspergillus sp. (A3) | 0.9       | 1.1     | Negative    | Negative    |
| Sterile mycelium (A2)  | 1.1       | Negative| Negative    | Negative    |
| Sterile mycelium (A5)  | 0.9       | Negative| Negative    | Negative    |
| Sterile mycelium (A6)  | 1         | Negative| Negative    | Negative    |
| Sterile mycelium (A7)  | Negative  | Negative| Negative    | Negative    |
| Sterile mycelium (A10) | 1.1       | 1.1     | Negative    | Negative    |
bacteria, then to use bio-assay guided fractionation to purify the active antibacterial compounds.

2. Materials and methods

2.1. Collection of plant materials and isolation and identification of endophytic fungi

Fresh healthy-looking stem, roots and leaves (both young and old) of *S. persica* were collected on 4 August 2015 from Okair Geological Reserve, 26°29′9″N, 48°24′54″E, located 160 km west of Dammam city, Saudi Arabia. Samples were kept in clean plastic bags in ice bags, returned to the laboratory and processed within 24 h (Abdel-Wahab et al., 2017). The plant species was identified by Dr. Jacob T. Pandalayil, curator of KSU Herbarium, Department of Botany and Microbiology, College of Science, King Saud University and the herbarium material of *S. persica* was preserved at the department’s herbarium. Isolation and identification of endophytic fungi using morphological and DNA sequences of ribosomal genes were described in details in Abdel-Wahab et al. (2017). Isolated fungi were grown in liquid cultures and natural products were extracted using ethyle acetate from culture filtrates. Resulted crude extracts were tested against pathogenic bacteria and fungi. Fungal isolated gave positive results were grown on large scale and resulted crude extracts were fractioned using silica gel columns and TLC sheets. Produced fractions were tested again and compounds in the actives sub-fractions were determined using mass spectrometry (GC-MS). Methods of growing fungal isolates, extraction and isolation of natural products, test organisms used, antimicrobial activity and isolation of metabolites were previously described (Abdel-Wahab et al., 2017).

3. Results and discussion

Forty-two fungal isolates were obtained from 135 young and old stem and 125 root segments. Those 42 isolates representing ten fungi include: *Trichoderma* sp. (the most common), two species of *Alternaria* (Fig. 3), *R. arrhizus* (Fig. 3) and *Aspergillus* sp. (Fig. 4) and 6 sterile mycelia. The ten fungi were grown in liquid culture and their crude extracts were tested against pathogenic bacteria and fungi. Twenty leaves (10 young and 10 old) of *S. persica* were processed for the isolation of fungal endophytes. However, no endophytic fungi were isolated from leaf samples. Nine crude extracts gave positive reactions against pathogenic of which two were chosen namely: *Alternaria* sp. (A8) and *R. arrhizus* (A9) for further study (Tables 1 and 2).

A few studies have been carried out to study endophytic fungi of *S. persica* (Korejo et al., 2014). Korejo et al. (2014) isolated eight endophytic fungi (including 2 *Aspergillus* spp., 3 *Penicillium* spp., *Fusarium solani*, *M. phaseolina* and *Rhizoctonia solani*) from 74 root, stem and leaves of Salvadoria species. In their study, *Aspergillus*
niger was the most common fungus followed by *A. flavus* and *Penicillium* spp. Endophytic fungi reported in the current study are totally different from endophytic fungi recorded in the previous studies from the same host (Korejo et al., 2014). Previous studies used different methods of endophytic fungi isolation where they surface sterilize the plant material and then ground them and use pour plate method. In the pour plate method, fast growing fungi like *Aspergillus* species overgrow other slow growing fungi. Also the structure of endophytic fungi communities from different geographical regions in the same host plant are frequently different (Jiang et al., 2010). The previous study has been carried in India while the present study in Saudi Arabia. Dhankhar et al. (2013a) isolated seventeen endophytic fungi from *S. oleoides* Decne in India and studied their abilities to produce natural products. Isolated endophytic fungi include: 10 *Aspergillus* spp., *C. herbarum*, *E. nigrum*, *F. moniliforme*, *P. chrysogenum*, *Phoma* sp. and *Pythium spinosa*. In another study, Dhankhar et al. (2013b) isolated 27 fungal species representing 18 fungal genera from 3750 samples of leaf segment, petiole and stem from five different sites of three seasons (summer, rainy and winter) were collected and analyzed. Antidiabetic and hypolipidemic activities of the crude extracts of the isolated fungi were tested and they obtained positive results from four fungal isolates (see Tables 3–6).

Thirty-seven bioactive chemical compounds were identified from the crude extracts of *Alternaria* sp. (A8) using GC-MS (Figs. 5–8). Thirteen major bioactive compounds were recorded namely: 1,2-Benzenedicarboxylic acid, bis (2-ethylhexyl) ester representing 51.15% of the crude extract, 6,8-dimethoxy-4-methyl-4H-chromene (10.87), 2,5-Cyclohexadien-1-one, 2,6-bis (1,1-dimethylethyl)-4-ethylidene- (3.94%), Cetene (3.32%), 1,2-Benzenedicarboxylic acid, dibutyl ester (3.23%), 1-Octadecene (2.64%), Benzeneethanol (2.47%), 1-Heptatriacotanol 16.65 6.34 536 Antioxidant, anticancer and anti-inflammatory. 17-Pentatriacontene 23.98 6.71 490 Antimicrobial 1-Heptatriacotanol 16.65 6.34 536 Antioxidant, anticancer and anti-inflammatory. Oleic acid, 3-(octadecyloxy)propyl Ester 30.95 5.82 592 Antifungal 7-Methyl-Z-tetradecen-1-o l acetate 26.65 3.25 268 Anticancer, anti-inflammatory, hepatoprotective. Z-5-Methyl-6-heneicos-1-one 23.09 2.13 322 Anticancer, anti-inflammatory, hepatoprotective. **Table 5** Major bioactive compounds identified from ethyl acetate crude of *Alternaria* sp. (isolate No. A8), sub-fraction (A8-1-6):  

| Bioactive compound | RT (min) | Peak area% | MW | Chemical structure | Pharmacological actions |
|--------------------|----------|------------|----|-------------------|-----------------------|
| Dasyracpidan-1-methanol, acetate (ester) | 24.73 | 30.33 | 326 | | Antimicrobial (Sundar and Pillaiy, 2016). |
| Cholest-22-ene-21-ol, 3,5-dehydro-6-methoxy-, pivalate | 25.41 | 22.14 | 498 | | |
| E-8-Methyl-9-tetradeccen-1-ol acetate | 26.19 | 15.49 | 268 | | |
| 9,10-Secocholesta-5,7,10(19)-triene-1,3-diol, 25-[(trimethylsilyloxy)-, (34,52,7E)- (Calcitriol) | 12.8 | 8.32 | 488 | | |
| 17-Pentatriacontene | 23.98 | 6.71 | 490 | | Antimicrobial |
| 1-Heptatriacotanol | 16.65 | 6.34 | 536 | | Antioxidant, anticancer and anti-inflammatory |
| Oleic acid, 3-(octadecyloxy)propyl Ester | 30.95 | 5.82 | 592 | | Antifungal (Abubacker and Devi, 2014). |
| 7-Methyl-Z-tetradecen-1-ol acetate | 26.65 | 3.25 | 268 | | Anticancer, anti-inflammatory, hepatoprotective |
| Z-5-Methyl-6-heneicos-1-one | 23.09 | 2.13 | 322 | | |
Presented by 51.15% of the ethyl acetate crude extract of the endophytic fungus *Alternaria* sp. (A8) isolated from the medicinal plant *S. persica*. 1,2-Benzenedicarboxylic acid, dibutyl ester (CAS) Butyl phthalate is among the major compounds recorded in this study and represented by 3.23% of the Crude. Phthalates compounds were reported from *Calotropis gigantean* (Habib and Karim, 2009), *Alchornea cordifolia* (Mavar-Manga et al., 2008) and *Aloe vera* (Lee et al., 2000). 1,2-Benzenedicarboxylic acid, dioctyl ester isolated from the ethyl acetate soluble sub-portion of the unripe fruits of *Nauclea latifolia* showed strong antibacterial activity against *Gram* positive bacteria (Ajoke et al., 2014). Phthalic Acid derivative produced by *Streptomyces bangladeshensis* showed strong antimicrobial activity (Al-Bari et al., 2006). 6,8-dimethoxy-4-methyl-4H-chromene (10.87%) is the second major compound in the active fraction of the crude. This compound seems to be a new compound and we will do more analytical work on it. 1-Octadecene is among the major compounds recorded in this study and represented by 2.64% of the Crude. Octadecane is an alkane hydrocarbon which possesses various activities such as anticancer, antioxidant and antimicrobial activities (Valderramas et al., 2008, Karmakar et al., 2011). Phenol, 2,4-bis[1,1-dimethylethyl]-(26.92%) was the major compound in this sub-fraction. 2,4-Di-tert-butylphenol (2,4-DTBP) is a natural compounds present in medicinal plants. It is reported to have herbicidal properties. It was produced by *Streptomyces* sp. and showed antibacterial activity against methicillin-resistant *Staphylococcus aureus* (MRSA) with mode of action against bacterial cell wall synthesis and also showed moderate cytotoxic activity (Chawawisit et al., 2015). 7-Methyl-Z-tetradecen-1-ol acetate (12.53%) was the second major compound reported in this sub-fraction. 7-Methyl-Z-tetradecen-1-ol acetate was isolated from the medicinal plant *Mentha viridis* (Hameed et al., 2015). 1-Hexadecanol, 2-methyl- (11.43%) was the third major compound recorded in this sub-fraction. 1-Hexadecanol, 2-methyl- was isolated from the methanolic extract of *S. aureus*. And it showed antimicrobial and antioxidant activity (Jaddoa et al., 2016).
Azulene, 1,4-dimethyl-7-(1-methylethyl) (10.76%) was the fourth major compound reported in this sub-fraction. Azulene, 1,4-dimethyl-7-(1-methylethyl) was isolated from the methanolic extract of the medicinal plant *Lindera nactusua* and it showed antibacterial activity (Wei et al., 2016). Dasycarpidan-1-methanol, acetate was the major compound in this sub-fraction. Dasycarpidan-1-methanol, acetate (ester) was the main antimicrobial bioactive compound that was isolated from the prickly custard apple (*Annona muricata*) and it was isolated from the methanolic and ethyl acetate crude extract from both peel and pulp and it was identified as best antibacterial agent (Karthikeyan et al., 2016). E-8-Methyl-9-tetradecen-1-ol acetate (15.49%) was the third major compound recorded in this sub-fraction. E-8-methyl-9-tetradecen-1-ol acetate was isolated from the ethanolic extract of the leaves of the medicinal plant *Mallotus tetracoccus* (Ramalakshmi and Muthuchelian, 2011).
Conflict of interest

The authors declare that they have no conflicts of interest

Acknowledgement

This project was supported by King Abdulaziz City of Science and Technology (KACST), Saudi Arabia (Project No. AT-35-155).

References

Abdel-Wahab, M.A., Bahkali, A.H., El-Gorban, A.M., Hodhod, M.S., 2017. Natural products of Nothophoma multilocularis sp. nov. an endophyte of the medicinal plant Rhazya stricta. Mycosphere 8, 1185–1200.

Abubacker, M.N., Devi, P.K., 2014. In vitro antifungal potentials of bioactive compound oleic acid, 3-(octadecyloxy) propyl ester isolated from Lepidagathis cristata Wild. (Acanthaceae) inflorescence. Asian Pac. Trop. Med. 7, S190–S193.

Ajoke, F.I., Kaita, H., Ilyas, M., 2014. Antibacterial Activity of 1,2-Benzenedicarboxylic acid, dioctyl ester isolated from the ethyl acetate soluble sub-portion of the unripe fruits of Nauclea latifolia. Int. J. Pure Appl. Bio. 2, 223–230.

Al-Bari, M.A.A., Sayeed, M.A., Rahman, M.S., Moosadik, M.A., 2006. Characterization and antimicrobial activities of a phthalic acid derivative produced by Streptomyces bangladeshensis- A novel species in Bangladesh. Res. J. Med. Med. Sci. 1, 77–81.

Albrechtsen, B.R., Broken, L., Farad, A., Hanger, A., Wedin, M., Carlson, J., Janssen, S., 2010. Endophytic fungi in European aspen (Populus tremula) leaves-diversity, detection, and a suggested correlation with herbivory resistance. Fungal Divers. 41, 17–28.

Aly, A.H., Debbab, A., Kjer, J., Proksch, P., 2010. Fungal endophytes from higher plants: a prolific source of phytochemicals and other bioactive natural products. Fungal Divers. 41, 1–16.

Arora, M., Siddiqui, A.A., Paliwal, S., Sood, P., 2014. A phyto-pharmacological overview on Salvadora oleoides Decne. Ind. J. Nat. Prod. Res. 5, 209–214.

Bos, G., 1993. The Miswak, an aspect of dental care in Islam. Med. Hist. 37, 68–79.

Botella, L., Santamaría, O., Díez, J.J., 2010. Fungi associated with the decline of Pinus halepensis in Spain. Fungal Divers. 40, 1–11.

Cai, Y.Z., Luo, Q., Sun, M., Corke, H., 2004. Antioxidant activity and phenolic compounds of 112 traditional Chinese medicinal plants associated with anticancer. Life Sci. 74, 2157–2184.

Carroll, G.C., 1986. The biology of endophytism in plants with particular reference to woody plants. In: Fokkema, N.J., van den Heuvel, J. (Eds.), Microbiology of the Phyllosphere. Cambridge University Press, Cambridge (UK), pp. 205–222.

Chawawisit, K., Bhoopong, P., Phupong, W., Lertcanawanichakul, M., 2015. AntimRSA activity, mode of action and cytotoxicity of 2,4-Di-tert-butylphenol produced by Streptomyces sp. KB1. Int. J. Pharm. Sci. Rev. Res. 35, 114–119.

Choi, W.Y., Rim, S.O., Lee, J.H., Lee, J.M., Lee, J.I., Cho, K.J., Rhee, I.K., Kwon, J.B., Kim, J.C., 2005. Isolation of gibberellins-producing fungi from the root of several Sesamum indicum plants. J. Micro. Biotech. 15, 22–28.
Li, W.C., Guo, S.Y., Guo, L.D., 2007a. Endophytic fungi associated with lichen
Lee, K.H., Kim, J.H., Lim, D.S., Kim, C.H., 2000. Anti-leukaemic and anti-mutagenic
Jiang, S., Duan, J.A., Tao, J.H., Yan, H., Zheng, J.B., 2010. Ecological distribution and
Hameed, I.H., Hussein, H.J., Kareem, M.A., Hamad, N.S., 2015. Identification of five
Hallmann, J., Berg, G., Schulz, B., 2006. Isolation procedures for endophytic
Habib, M.R., Karim, M.R., 2009. Antimicrobial and cytotoxic activity of Di-(2-
Ghimire, S.R., Charlton, N.D., Bell, J.D., Krishnamurthy, Y.L., Craven, K.D., 2011.
Dhankhar, S., Dhankhar, S., Yadav, J.P., 2013b. Investigations towards new
Dhankhar, S., Dhankhar, S., Yadav, J.P., 2013a. Investigating antimicrobial properties
Chuah, T.S., Norhafizah, M.Z., Ismail, B.S., 2015. Evaluation of the biochemical and
Bhattacharya, B., Chaudhury, S., Datta, S., Roy, S., Chakraborty, A., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakraborty, A., Bhattacharya, B., Datta, S., Roy, S., 2016. Antimicrobial and antiviral activity of certain endophytic fungi isolated from medicinal plants of medicinal plants.
Chakrabo...