Chapter 2
Antifungal Plants of Iran: An Insight into Ecology, Chemistry, and Molecular Biology

Mehdi Razzaghi-Abyaneh, Masoomeh Shams-Ghahfarokhi and Mahendra Rai

Abstract Worldwide occurrence of fungal infections has been dramatically increased in recent years due to a continuous increase in immunosuppressive conditions like AIDS, organ transplantation and hematologic malignancies. Fungal infections are major concerns in Iran with an increasing numbers of new reports from superficial to deep hospital-acquired infections every year. Although there are no comprehensive data on the real incidence of fungal infections, especially systemic ones in Iran, about 50 % of suspected individuals referred to our laboratory (Mycology Department of the Pasteur Institute of Iran) were found to have dermatophytosis, candidiasis, and pityriasis versicolor (Sadeghi et al. 2011). Plants are rich sources of beneficial secondary metabolites which are attractive as flavors, fragrances, pesticides, pharmaceuticals, and antimicrobials. Increasing trends of health organizations and pharmaceutical industries to use plants as safe and effective alternative sources of synthetic antifungals are due to major problems of slow growing and high costs of synthetic pharmaceutics, their life-threatening side effects, rapid increase in new fungal infections, and dramatic emergence of multidrug-resistant fungal pathogens. Interestingly, antifungal drug discovery from medicinal plants is a rapidly growing industry worldwide (WHO 2002). World trade of medicinal plants is now more than 43 billion dollars and has been predicted to reach to 5 trillion dollars in 2050. It has been estimated that around 7,500–8,000 plant species are growing in Iran of which only 130 species have been routinely used as anti-infective drugs in traditional medicine (Rechinger 1982). Iran's contribution to this market is about 60 million dollars, which

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increases every year (Noorhosseini Niyaki et al. 2011). This chapter highlights the current status of antifungal plant flora of Iran regarding their ecology, biochemistry, and molecular biology. Special attention will be made to effective plant components responsible for antifungal properties.

Abbreviations

Albugo	*A. candida*
Aspergillus	*A. niger*, *A. flavus*, *A. parasiticus*, *A. fumigatus*
Botrytis	*B. cinerea*
Candida	*C. albicans*, *C. glabrata*, *C. tropicalis, C. parapsilosis*
Cladosporium	*C. cucumerinum*
Cochliobolus	*C. sativus*
Corynespora	*C. cassilicola*
Epidermophyton	*E. floccosum*
Fusarium	*F. oxysporum* f. sp. *radicis-cucumerinum*, *F. solani*, *F. oxysporum*, *F. poae*, *F. equiceti, F. verticillioides*
Macrophomina	*M. phaseolina*
Malassezia	*M. furfur*, *M. globosa*, *M. obtusa*
Microsporum	*M. canis*, *M. gypseum*
Phytophthora	*P. drechsleri*
Rhizoctonia	*R. solani*
Saccharomyces	*S. cereviciae*
Trichoderma	*T. harzianum*
Trichophyton	*T. mentagrophytes*, *T. rubrum*
Verticillium	*V. dahliae*

2.1 Introduction

Despite tremendous success in development of medical sciences in recent years, infectious diseases remain the second leading cause of human death worldwide (WHO 2002). Fungi comprise a major part of biodiversity, second to insects owing to have an estimated number of 1.5 million species on our planet. Among 100,000 known fungal species, around 400 species are known as human and animal pathogens. Although fungal diseases are not important as much as bacterial and viral infections, however, they are increasing in number and severity due to easy airborne distribution of fungal spores as infective propagules and unique adaptability to various environmental conditions. Increasing resistance of fungal pathogens especially life-threatening genera, that is, *Aspergillus* and *Candida* to synthetic antibiotics urged pharmaceutical industries all over the world to search for safer and more effective alternatives from natural sources. Among beneficial biodiversity, plants are in the first line of such investigations due to having a large number of antifungal metabolites with unique structural diversity (Balunas and Kinghorn 2005). Plant metabolites have advantages to microbial metabolites regarding their low molecular weights, which makes them suitable for formulating as antifungal drugs (Cowan 1999).

The history of using plants as healing agents dates back to around 60,000 years ago when the Neanderthals, landed in present-day Iraq, used hollyhock (*Alcea rosea* L.) as a remedy (Stockwell 1988). Plants are important not only as essential part of the ecosystem as food but also for being unique sources of natural antimicrobials which makes them interesting as alternatives of synthetic antimicrobials (Clark 1996; Cowan 1999; Bakkali et al. 2008; Razzaghi-Abyaneh et al. 2010; Abdallah 2011; Razzaghi-Abyaneh and Shams-Ghahfarokhi 2011). It has been estimated that around 25,000–50,000 plant species exist in our planet have ethnobotanical importance (Borris 1996).

Iran with an area of 1,648,195 million km^2 is the eighteenth largest country in the world located in three spheres of Asia (West, Central, and South) in Middle East. It has about 33 % of cultivable land, 14 million ha pasture, 60 million ha steppes, and 16 million ha deserts. Because of particular climatic significance owing to possess 11 climates out of 13 world climates, Iran is a rich source of medicinal plants, and some of them were employed in traditional medicine for centuries (Sharafzadeh and Alizadeh 2012).

The first description of use of medicinal plants as remedies in Iran dates back to the earliest known civilizations, the Sumerians in 3000 B.C. (Price 2001). It seems that the earliest and the oldest production in prose of the Neo-Persian literature on pharmacology is the "kitabulabnyat and haqa'iq-uladviyat" or "Book of the Foundations of the True Properties of the Remedies" written about 970 A.D. by the Persian Physician Abu Mansur. The book has been examined by R. Seligmann from the oldest existent Persian manuscript of Vienna dated 1055. During 200–460 BC, the famous university and the hospital at Jundishapur were established. It was a start to the golden age of herbal-based medicine in Iran which reached to the top by the famous scientists Zakariya-Al-Razi (Rhazes 865–925), Al-Biruni (973–1048), and Abu Ali Sina (Avicenna 980–1037). *The Canon of Medicine* (Al-Qanoon fi al-Tibb, The Laws of Medicine), written by Avicenna, described the ethnobotanical and therapeutic effects of about 811 medicinal plants. It was a standard medical text in Europe and the Islamic world until the eighteenth century and played a crucial role in European Renaissance (Price 2001).

In a Tehran publication of 1874 written in French by Professor J.L. Schlimmer of the Polytechnic College of Teheran entitled "Terminologie Médico-Pharmaceutique et Anthropologique Francaise-Persane," a full list of medicinal plants of Iran was published. In 1890, Dr. J.E.T. Aitchison botanically explored portions of Iran and the neighboring regions in "Notes on the Products of Western Afghanistan and of North–Eastern Persia" published in Edinburgh. During 1929–1958, five collections of medicinal plants of Iran were published which comprised about 200,000 herbarium specimens from different parts of Iran (Pasrsa 1959a, b, c; 1960). Three of these collections were published in "Useful plants and drugs of

Iran and Iraq" by David Hooper, 1937. Other two collections were originated from the work of Ahmad Pasha, founder and leader of the Museum of Natural History of Teheran, during 1946–1958, which published under the names "Flore de I'Iran" and "Medicinal plants and drugs of plant origin in Iran; parts I–IV."

We represent here current data about antifungal properties of essential oils and extracts prepared from various parts (leaves, stems, roots, flowers, seeds, shoots) of indigenous plants of Iran.

2.2 Medicinal Plants with Antifungal Properties

A total of 83 plant species from flora of Iran distributed into 28 families were found in various surveys to have antifungal properties. Table 2.1 illustrates detailed data about these plants and their bioactive metabolites inhibitory to a wide array of fungal pathogens. The following sections will discuss the antifungal properties of the most effective plants listed in Table 2.1.

2.2.1 Matricaria chamomilla

Matricaria chamomilla L. (syn: *M. recutita* L.; German chamomile) resides in the Asteraceae (Compositae) family and is the most important species within the genus, and it is endemic to Iran as a carminative, stimulant, and febrifuge remedy. It has a long history of application in herbal medicine as carminative and anti-inflammatory agent. Camomile tea prepared from the daisies is given to relieve intercostal neuralgia. An infusion of the drug is prescribed for dysentery.

Essential oil of plant flowers has shown antifungal properties by inhibiting the growth and conidiogenesis of *Aspergillus niger* (Tolouee et al. 2010). Complementary electron microscopic studies revealed that the plant oil inhibited *A. niger* growth by affecting fungal cell membrane, probably through interaction with ergosterol biosynthesis (Fig. 2.1). A monocyclic sesquiterpene alcohol named α-bisabolol, the main component of plant oil, is accounted for antifungal properties because of structural similarities to zymosterol, an important intermediate in ergosterol biosynthesis pathway (Pauli 2005, 2006).

2.2.2 Stachys Inflata

The genus *Stachys* (Lamiaceae) is represented by 270 species with 34 species found in Iran of which 13 species are endemic (Zargari 1992; Ghahreman 1995). *Stachys* species are well known to have chemically diverse compounds including phenylethanoid glycosides, terpenoids, steroids, diterpenes, and flavonoids.

Table 2.1 General characteristics of antifungal plant flora of Iran

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
Alliaceae	*Allium cepa* L.	Onion	Bulb	Aqueous extract	0.125–2 mg/ml-MIC_{50}	*M. furfur*	Shams-Ghahfarokhi et al. (2003), (2004), (2006)
						C. albicans	
					2–8 mg/ml-MIC_{90}		
						C. glabrata	
						C. tropicalis	
						C. parapsilosis	
	Allium sativum L.	Garlic			0.0039–0.0312 mg/ml-MIC_{50}	*T. mentagrophytes*	
						T. rubrum	
						M. canis	
						M. gypseum	
						E. floccosum	
					0.0156–0.125 mg/ml-MIC_{90}		
Anacardiaceae	*Rhus coriaria*	Sumac (Kermanshsh)	Shoot	Methanolic extract	50 ppm-MFC	*A. candida*	Omranpour et al. (2011)
Apiaceae	*Conium maculatum* L.	Hemlock	Leaves	Essential oil	90 % inhibition at 1,000 µg/ml	*A. parasiticus*	Razzaghi-Abyaneh et al. (2009)
	Ferula gummosa	Galbanum	Aerial parts	Essential oil (ß-pinene as the main constituent; 54.4 %)	1,815 µg/ml-IC_{50}	*A. parasiticus*	Alinezhad et al. (2011)
	Diplotaenia damavandica Mozaff. Ex Hedge and Lamond	Kozal	Leaves	Essential oil		*C. albicans*	Eftekhar et al. (2005)
						A. niger	
						S. cereviciae	
				Oil constituents tested;	3.6–7.2 mg/ml-MICs		
				– Dillapiol	>64.3 mM		
				– Terpinolene	6.6–13.2 mM		
				– γ-terpinene	55.1->110.1 mM		
				– *p*-cymene	>55.9 mM-MICs		

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
	Cuminum cyminum	Cumin Ziree in Percian	Aerial parts	Essential oil (α-pinene, limonene and 1,8-cineol as the main constituents; 30, 21 and 18.5 %)	30 µl/disk	*M. furfur*	Naeini et al. (2011)
						M. globosa	
						M. obtusa	
				Essential oil	59–578 µg/ml-MICs	*F. solani*	Naeini et al. (2010)
						F. oxysporum	
						F. verticillioides	
						F. poae	
						F. equiseti	
				Essential oil	280 µg/ml-MIC	*C. albicans*	Naeini et al. (2009)
	Heracleum persicum Desf. Ex Fisch.	Persian cow-parsnip	Aerial parts	Essential oil	70–4,500 µg/ml-MICs	*F. solani*	Naeini et al. (2010)
						F. oxysporum	
		Golpar in Percian					
						F. verticillioides	
						F. poae	
						F. equiseti	
				Essential oil (*trans*-anethole as the main constituent; 25.0 %)	2 mg/disk	*A. niger*	Firuzi et al. (2010)
					–Inhibition zone of ~7 mm	*C. albicans*	
				Essential oil	1,100 µg/ml-MIC	*C. albicans*	Naeini et al. (2009)
			Seeds	Ethyl acetate extract	370 µg/ml-IC_{50}	*A. parasiticus*	Alinezhad et al. (2011)
	Heracleum pastinacifolium K. Koch	Hogwood	Aerial parts	Essential oil (myristicin as the main constituent; 53.6 %)	2 mg/disk	*A. niger*	Firuzi et al. (2010)
					–Inhibition zone of ~7 mm	*C. albicans*	

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
	Heracleum rechingeri Manden	Hogwood		Essential oil (hexyl butanoate as the main constituent; 29.7%)			
	Heracleum transcaucasicum Manden	Hogwood		Essential oil (elemicin as the main constituent; 41.1 %)			
	Foeniculum vulgare	Fennel	Roots	Essential oil (dillapiol as the main constituent; 90.1 %)	700 μg/ml-IC_{50}	*A. parasiticus*	Alinezhad et al. (2011)
			Flowers	Essential oil (*trans*-anethole as the main constituent; 68.4 %)	~70 % inhibition at 2,000 μg/ml		
			Aerial parts	Essential oil	64–1,232 μg/ml-MICs	*F. solani* *F. oxysporum* *F. verticillioides* *F. poae* *F. equiseti*	Naeini et al. (2010)
				Essential oil	300 μg/ml	*C. albicans*	Naeini et al. (2009)
	Foeniculum miller	Hay	Leaves	Essential oil	~15.0 % inhibition at 1,000 μg/ml	*A. parasiticus*	Razzaghi-Abyaneh et al. (2009)
	Semenovia tragioides Boiss.	- (Kashan)	Aerial parts	Essential oil (lavandulyl acetate, geranyl acetate and *trans*-ocimene as the main constituents; 25.5, 12.5 and 8.8 %) Methanolic extract	5 mg/ml-MIC	*C. albicans (no effect on A. niger)*	Bamoniri et al. (2010)
	Pimpinella anisum L.	Anise	Aerial parts	Essential oil	300 μg/ml-MIC	*C. albicans*	Naeini et al. (2009)
			Seeds	Methanolic extract	16–64 mg/ml-MICs	*C. albicans* *M. canis*	Yazdani et al. (2009)

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
						T. mentagrophytes	
						E. floccosum	
	Trechyspermum copticum	Ajowan	Fruits	Essential oil (thymol, γ-terpinene and O-cymene as the main constituents: 45.9, 20.6 and 19.0 %)	0.25–0.5 µg/ml-MICs	*C. albicans*	Mahboubi and Kazempour (2011)
						C. glabrata	
						A. niger	
					0.25–1.0 µg/ml-MLCs		
						A. flavus	
						A. parasiticus	
	Trachyspermum ammi Spraque ex Turrill.	Ajowan	Seeds	Essential oil	10–55 µg/disk	*C. albicans*	Ghasemi-Pirbalouti et al. (2009)
					Inhibition zone of 18–21 mm		
	Bunium persicum Boiss.	Kala jeera	Fruits	Essential oil	8–256 µg/ml	*A. niger*	Ghasemi-Pirbalouti et al. (2011)
						A. flavus	
						A. fumigatus	
Asteraceae	*Centaurea behen* Linn.	Safed behman	Whole plant	Aqueous and methanolic extracts	5 mg/disk	*R. solani*	Bahraminejad et al. (2011)
						F. oxysporum	
						Cochliobolus sativus	
					Inhibition zone of 6.2–15.2 mm		
	Achillea millefolium subsp. *elborsensis*	Yarrow Plumajillo (Alborz)	Flowers	Essential oil (chamazulene as the main constituent; 48.9 %)	580 µg/ml-IC_{50}	*A. parasiticus*	Alinezhad et al. (2011)
	Matricaria chamomilla L.	German chamomile	Flowers	Essential oil (α-bisabolol as the main constituent; 56.86 %)	300 µg/ml-IC_{50}	*A. niger*	Tolouee et al. (2010)

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
	Artemisia scoparia Waldst. and Kitam.	Redstem wormwood	Aerial parts	Methanolic extract	80 mg/ml, 0.2 ml/cup inhibition zone of 13.6 mm	*C. albicans*	Ramezani et al. (2004)
	Artemisia dracunculus	Tarragon	Leaves	Essential oil (terpinolene, *trans*-ocimene and *trans*-anethole as the main constituents; 12.4, 20.6 and 21.2 %)	70.1 % inhibition at 1,000 μg/ml	*A. parasiticus*	Razzaghi-Abyaneh et al. (2009)
	Artemisia sieberi Besser	Wormwood (Ghom-Markazi)	Aerial parts	Essential oil (β-thujone, camphor and α-thujone as the main constituents; 23.0, 19.5 and 15.0 %)	37.4–4,781.3 μg/ml-MICs	*C. glabrata*	Khosravi et al. (2011)
					597.6–4,781.3 μg/ml-MFCs		
				Essential oil	1,100 μg/ml-MIC	*C. albicans*	Naeini et al. (2009)
	Artemisia kermanensis Podl.	Wormwood (Kerman)	Aerial parts	Essential oil	10–55 μg/disk	*C. albicans*	Ghasemi-Pirbalouti et al. (2009)
					Inhibition zone of 7–9 mm		
	Tanacetum polycephalum	Tansy (Chaharmahal va Bakhtiari)	Flowers		10–55 μg/disk		
					Inhibition zone of 9–20 mm		
Caryophyllaceae	*Vaccaria pyramidata* Medik.	Cowherb (Kermanshah)	Shoot	Methanolic extract	250 ppm-MFC	*A. candida*	Omranpour et al. (2011)
Ephedraceae	*Ephedra major* Host.	Ephedra	Roots	Methanolic extract	>1,000 μg/ml-MIC	*A. parasiticus*	Bagheri-Gavkosh et al. (2009)
Fabaceae	*Glycyrrhiza glabra*	Licorice	Leaves	80 % ethanolic extract	25.0–83.3 mg/ml-MICs	*A. flavus* *A. fumigatus* *A. niger*	Rashidi et al. (2011)
	Dalbergia sissoo	Amerimnon sissoo (Khuzestan)	Aerial parts	80% ethanolic extract	500–2,000 μg/ml-MICs	*A. niger*	Arabi and Sardari (2010)

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
						C. albicans	
						A. fumigatus	
	Lathyrus pratensis	Meadow pea (Mazandaran)					
	Hippocrepis unisiliquosa L.	Budellina (Khuzestan)					
	Oreophysa microphylla Bunge ex Boiss.	-(Tehran)					
	Onobrychis altissima Grossh.	Chickwood (Ardebil)					
	Argyrolobium roseum (Cambess.) Jaub. & Spach	-(Hormozgan)					
	Hymenocarpus circinnatus (L.) Savi.	Disk trefoil (Lorestan)					
	Astragalus stepporum	Milk-vetch (Khuzestan)					
	Ammodendron persicum	-(Khorasan)					
	Sophora alopecuroides L.	Lighiyellow sophora (Isfahan)					
	Taverniera cuneifolia (Roth)	Taverniera (Kerman)					
	Ebenus stellata Boiss.	Ebenus (Fars)					
Fagaceae	*Ziziphus spina-christi* (L.) Willd.	Nubk tree (Ilam)	Fruits	Aqueous extract	10–55 µg/disk	*C. albicans*	Ghasemi-Pirbalouti et al. (2009)
					Inhibition zone of 18–34 mm		
Geraniaceae	*Pelargonium graveolens*	Geranium	Aerial parts	Essential oil (citronelol and geraniol as the main constituents; 28.2 and 22.1 %)	30 µl/disk	*M. furfur*	Naeini et al. (2011)
						M. globosa	
						M. obtusa	
				Essential oil	250 µg/ml	*C. albicans*	Naeini et al. (2009)

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
Hypericaceae	*Hypericum perforatum* L.	Amber (Kermanshah)	Shoot	Methanolic extract	100 ppm-MFC	*A. candida*	Omranpour et al. (2011)
Illiciaceae	*Illicium verum* Hook. f.	Star anise	Fruits	Methanolic extract	4–64 mg/ml	*A. niger* *C. albicans* *M. canis* *T. mentagrophytes* *E. floccosum*	Yazdani et al. (2009)
Lamiaceae (Labiateae)	*Hymenocrater calycinus* (Boiss.) Benth.	Oraman's tulip (Firuzkuh)	Aerial parts	Rosmarinic acid (from ethyl acetate and methanolic extracts)	250 µg/ml	*C. albicans*	Gohari et al. (2009)
					1,000 µg/ml-MICs	*A. niger*	
	Origanum vulgare	Oregano (Ghom-Markazi)	Aerial parts	Essential oil (linalool, and thymol as the main constituents; 42.0 and 25.1 %)	0.3–1,100 µg/ml-MICs	*C. glabrata*	Khosravi et al. (2011)
					2.2–2,200 µg/ml-MFCs		
	Salvia officinalis	Common sage	Leaves	80% ethanolic extract	16.67–133.34 mg/ml-MICs	*A. flavus*	Rashidi et al. (2011)
	Lavandula officinalis	Lavender				*A. fumigatus* *A. niger*	
	Zataria multiflora Boiss. Sattar	Zattar Avishan	Aerial parts	Essential oil (thymol as the main constituent; 50–70 %)	0.25–2 mg/ml	*C. albicans*	Saei-Dehkordi et al. (2010)
					0.062–0.5 mg/ml-MICs	*C. tropicalis*	
					≥400 ppm-MFC	*A. flavus*	Gandomi et al. (2009)
				Essential oil (carvacrol as the main constituent; ∼60 %)	30 µl/disk	*M. furfur*	Naeini et al. (2011)
						M. globosa *M. obtusa*	
				Essential oil	66–612 µg/ml-MICs	*F. solani* *F. oxysporum* *F. verticillioides*	Naeini et al. (2010)

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
						F. poae	
						F. equiseti	
				Essential oil	150 μg/ml-MIC	*C. albicans*	Naeini et al. (2009)
				Essential oil	8–256 μg/ml	*A. niger*	Ghasemi-Pirbalouti et al. (2011)
						A. fumigatus	
					128 μg/ml; MFC	*A. flavus*	
						A. parasiticus	
	Satureja Khuzistanica Jamzad.	Marzeh (Khoramabad-Lorestan)	Aerial parts	Methanolic extract	2–8 mg/ml	*A. niger*	Amanlou et al. (2004)
					1–4 mg/ml-MICs	*C. albicans*	
		Marzeh (Dezful-Khuzestan)		80 % ethanolic extract	625-2,500 μg/ml-MICs	*A. flavus*	Sadeghi-Nejad et al. (2010)
						A. niger	
						Penicillium sp.	
						Fusarium sp.	
						Alternaria sp.	
						Rhizopus sp.	
						Mucor sp.	
	Ziziphora clinopodioides Lam.	Kakuti-e-Kuhi	Aerial parts	Essential oil	560 μg/ml-MIC	*C. albicans*	Naeini et al. (2009)
	Satureja hortensis	Summer savory Koc Out	Leaves	Thymol	0.86 μM	*A. parasiticus*	Razzaghi-Abyaneh et al. (2008)
				Carvacrol	0.79 μM-IC_{50}		
			Aerial parts	Essential oil	1,100 μg/ml-MIC	*C. albicans*	Naeini et al. (2009)
				Essential oil (thymol, *p*-cymene, γ-terpinene and carvacrol as the main constituents; 28.2, 19.6, 16.0 and 11.0 %)	0.06–1 μg/ml-MICs	*C. albicans*	Mahboubi and Kazempour (2011)
						C. glabrata	
						A. niger	

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
						A. flavus	
						A. parasiticus	
	Mentha spicata	Spearmint (Yazd)	Aerial parts	Essential oil	1–5 μl disks on PDA for 4 days at 25 C	*F. oxysporum* f. sp. *radicis-cucumerinum*	Nosrati et al. (2011)
				Essential oil	2,300 μg/ml	*C. albicans*	Naeini et al. (2009)
			Leaves	Essential oil (piperitenone oxide and *cis*-carveol as the main constituents; 34.7 and 21.7 %)	35 μg/ml-IC_{50}	*A. parasiticus*	Alinezhad et al. (2011)
	Mentha piperita	Spearmint (Damavand-Tehran)	Leaves	Essential oil (α-terpinene, pipertitinone oxide, *trans*-carveol and isomanthone as the main constituents; 19.7, 19.3, 14.5 and 10.3 %)	1 μl/ml-MIC	*C. albicans*	Yadegarinia et al. (2006)
					≥2 μl/ml-MLC		
	Stachys inflata Benth.	–(Kashan-Isfahan)	Aerial parts	Essential oil	No effect	*C. albicans*	Ebrahimabadi et al. (2010a)
				– Linalool (28.55 % of the oil)	125-500 μg/ml	*A. niger*	
				– α-terpineol (9.45 % of the oil)	250–500 μg/ml		
				Methanolic extract	250 μg/ml only for *C. albicans*-MICs		
	Hymenocrater longiflorus Benth.	Oraman's tulip (Kermanshah)	Aerial parts	Essential oil (Δ-cadinol and α-pinene as the main constituents; 18.49 and 10.16 %) Methanolic extract	240–480 μg/ml-MICs	*C. albicans*	Ahmadi et al. (2010)

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
					>10 µg/ml-MICs	*A. niger*	
	Salvia eremophila Boiss.	Sage (Kashan-Isfahan)	Aerial parts	Essential oil (borneol, α-pinene and bornyl acetate as the main constituents; 21.83, 18.80 and 18.68 %)	250 µg/ml	*C. albicans*	Ebrahimabadi et al. (2010b)
					>500 µg/ml-MICs	*A. niger*	
				Methanolic extract	No effect		
	Rosmarinus officinalis Linn.	Rosemary	Aerial parts	Essential oil	2,300 µg/ml-MIC	*C. albicans*	Naeini et al. (2009)
	Thymus eriocalyx	Thyme	Aerial parts	Essential oil (thymol as the main constituent; 64.3 %)		*A. parasiticus*	Rasooli and Razzaghi-Abyaneh (2004)
	Thymus x-prolock			Essential oil (ß-phellandrene as the main constituent; 39.4 %)			
	Thymus vulgaris	Thyme	Leaves	Essential oil (thymol as the main constituent; 70.99 %)	1,000 µg/ml-MFC	*A. parasiticus*	Razzaghi-Abyaneh et al. (2009)
	Thymus daenensis Celak.	Thyme (Chaharmahal va Bakhtiari)	Aerial parts	Essential oil	10–55 µl/disk	*C. albicans*	Ghasemi-Pirbalouti et al. (2009)
					Inhibition zone of 20–23 mm		
	Thymbra spicata L.	Thyme (Ilam)					
	Satureja bachtiarica Bunge.	Savory (Chaharmahal va Bakhtiari)					
Liliaceae	*Allium heamanthoides*	Musir (Kermanshah)	Corm	Methanolic extract	250 ppm-MFC	*A. candida*	Omranpour et al. (2011)
Lythraceae	*Lawsonia inermis* L.	Henna	Leaves	Extracts (aqueous, chloroformic, methanolic)	0.25–4 %; v/v	*Malassezia* sp.	Berenji et al. (2010)
Malvaceae	*Althaea officinalis*	Marshmallow	Leaves	80 % ethanolic extract	50.0–83.34 mg/ml-MICs	*A. flavus*	Rashidi et al. (2011)

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
						A. fumigatus	
						A. niger	
Meliaceae	*Azadirachta indica* A. Juss	Neem	Leaves seeds	Aqueous extracts	>90 % inhibition at 50 % v/v concentrations	*A. parasiticus*	Allameh et al. (2001)
		Margosa (Bandarabbas)					
							Razzaghi-Abyaneh et al. (2005)
							Ghorbanian et al. (2007)
			Seeds	Essential oil	66.4 % inhibition at 1,000 μg/ml	*A. parasiticus*	Razzaghi-Abyaneh et al. (2009)
Myrtaceae	*Myrtus commonis* Linn.	Myrtle	Leaves	Essential oil (1,8-cineole, α-pinene and linalool as the main constituents; 36.1, 22.5 and 8.4 %)	8–16 μg/ml-MICs	*C. albicans*	Mahboubi and Bidgoli (2010)
						A. niger	
						A. flavus	
						A. parasiticus	
				Essential oil (α-pinene, limonene, 1,8-cineole and linalool as the main constituents; 29.1, 21.5, 17.9 and 10.4 %)	2 μl/ml		
-MIC	*C. albicans*	Yadegarinia et al. (2006)					
					4–8 μl/ml-MLC		
	Syzygium aromaticum (Eugenia caryophyllata)	Clove (Kermanshah)	Shoot	Methanolic extract	100 ppm-MFC	*A. candida*	Omranpour et al. (2011)
Nitrariaceae	*Peganum harmala*	African rue (Kashan)	Seeds	Aqueous extract	1.0 %, v/v in PDA plates	*Alternaria* sp.	Sarpeleh et al. (2009)

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
						B. cinerea *C. cucumerinum* *C. cassilicola* *F. oxysporum* *M. phaseolina* *P. drechsleri* *T. harzianum* *Ulocladium* sp. *V. dahliae*	
Papaveraceae	*Glaucium oxylobum* Boiss. et Buhse	Horned poppy	Aerial parts	Methanolic extract	10 mg/ml		
–active against MC, MG, TM and EF	*M. canis* (MC)	Morteza-Semnani et al. (2003)					
		Lotus sweetjuice (Roodbar-Guilan)				*M. gypseum* (MG)	
						T. mentagrophytes (TM)	
				300 μg/ml of isolated alkaloids:			
						E. floccosum (EF)	
				– Dicentrine	– Active against MC, MG, TM and EF		
				– Glaucine	– Active against MC, MG and TM		
				– Protopine	– Active against MC and TM		
				– α-allocryptopine	– Active against MG and EF		
				– *O*-methylflavinantine	– No antifungal activity		
Poaceae	*Avena sativa* L.	Common oat	Roots	Methanolic extract	5 mg/disk Inhibition zone of 6.1–9.6 mm	*R. solani*	Bahraminejad et al. (2011)

(continued)

Table 2.1 (continued)

Family	Species	Common name (place of collection)	Part used	Effective component (s)	Inhibitory concentration	Affected fungi	Reference
						F. oxysporum	
Primulaceae	*Anagallis arvensis* L.	Red chickwood	Whole plant				
						C. sativus	
		Red chickwood (Kermanshah)	Shoot	Methanolic extract	50 ppm-MFC	*A. candida*	Omranpour et al. (2011)
Ranunculaceae	*Nigella sativa*	Black cumin Siyahdaneh	Aerial parts	Essential oil	2,300 μg/ml-MIC	*C. albicans*	Naeini et al. (2009)
Rhamnaceae	*Quercus brantii* Lindl.	Oak manna tree (Ilam)	Fruits	Aqueous extract	10–55 μg/disk inhibition zone of 6–7 mm	*C. albicans*	Ghasemi-Pirbalouti et al. (2009)
Rosaceae	*Mespilus germanica*	Common medlar (Kermanshah)	Leaves	Methanolic extract	50 ppm-MFC	*A. candida*	Omranpour et al. (2011)
Rutaceae	*Citrus aurantifolia* Swingle	Aour lime	Leaves	Essential oil (limonene as the main constituent; 85.5 %)	1,000 μg/ml-IC_{50}	*A. parasiticus*	Razzaghi-Abyaneh et al. (2009)
Scrophulariaceae	*Scrophularia striata* Boiss.	Figwort	Leaves	Aqueous extract	10–55 μg/disk inhibition zone of 22–35 mm	*C. albicans*	Ghasemi-Pirbalouti et al. (2009)
	Verbascum nigrum L.	Dark Mullein	Shoot	Methanolic extract	100 ppm-MFC	*A. candida*	Omranpour et al. (2011)
Zingiberaceae	*Zingiber officinale* Rosc.	Ginger (Kermanshah)	Rhizome	Methanolic extract	100 ppm-MFC	*A. candida*	Omranpour et al. (2011)
Zygophyllaceae	*Tribulus terrestris* L.	Puncture vine	Shoot	Aqueous and methanolic extracts	5 mg/disk	*R. solani*	Bahraminejad et al. (2011)
						F. oxysporum	
					Inhibition zone of 6.6–17.6 mm		
						C. sativus	
			Roots				
		Caltrop					
		Yellow vine					
Plant resin-like exudates	Iranian Propolis	Balsam (Tehran-Khojir)	Exudates	Ethanolic extract (70 % in water)	250 μg/ml	*C. albicans*	Mohammadzadeh et al. (2007)
					500 μg/ml	*A. niger*	

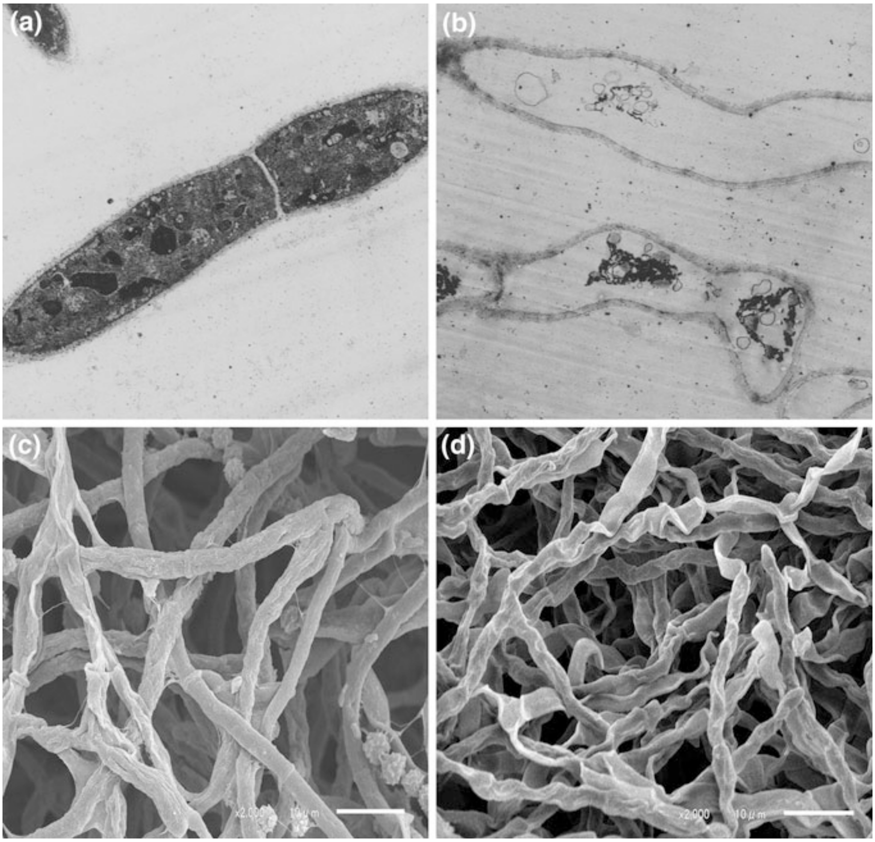
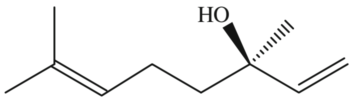


Fig. 2.1 Electron microscopic study of *A. niger* grown on PDB with or without *M. chamomilla* flower essential oil (EO; 1,000 μg/ml) after 96-h incubation at 28 °C. Transmission electron micrographs (*TEM*) of control (untreated) fungal mycelia (**a**) show uniform hypha with normal septum, walls, and organelles, while TEM of EO-treated sample (**b**) indicates deformation of hyphae and massive destruction of cellular organelles. Scanning electron micrographs (*SEM*) reveal normal conidia and hyphae and conidiophores with uniform tubular shape in all parts for control sample (**c**), while it shows massive collapse and folding of whole hyphae and lack of conidiation for EO-treated sample (**d**)

Stachys inflata Benth. (Persian names: poulk, gole arghavan) is one of the endemic species of Iran with routine application as herbal tea in the treatment for various infections and inflammatory disorders (Zargari 1992).

Methanolic extract of plant aerial parts was shown to effectively inhibit the growth of *Candida albicans*, while the plant essential oil did not affect fungal growth even at a concentration of 1,000 μg/ml (Ebrahimabadi et al. 2010a). The main plant constituents, that is, linalool **1** ($C_{10}H_{18}O$, 154.24 g/mol) and α-terpineol **2** ($C_{10}H_{18}O$, 154.24 g/mol), were shown to be responsible for antifungal properties with minimal inhibitory concentrations (MICs) between 125 and 500 μg/ml for *C.*

albicans and *A. niger*.



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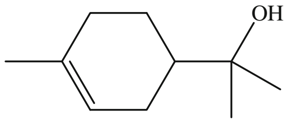

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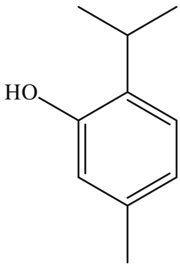
2.2.3 Satureja hortensis

The genus *Satureja* (Lamiaceae) comprises about 30 species called savories (Marzeh in Persian) with 12 species found in Iran of which three species, that is, *S. hortensis* ("summer savory" or "Koc Out"), *S. khuzistanica*, and *S. bachtiarica*, are the most important ones. Besides the routine use in food industry as aromatic and flavoring agents, they have received major consideration due to their anti-inflammatory, antioxidant, antibacterial, and antifungal properties (Sharafzadeh and Alizadeh 2012).

Methanolic extracts of aerial parts of *S. khuzistanica* showed strong inhibitory activity toward the growth of *C. albicans* and *A. niger* with MICs of 1–8 mg/ml (Amanlou et al. 2004). Essential oil of aerial parts of *S. bachtiarica* is found to be effectively inhibiting cell growth of *C. albicans* in concentrations of 10–55 μg/disk in disk diffusion assay (Ghasemi-Pirbalouti et al. 2009). Essential oil of *S. hortensis* leaves inhibited mycelia growth of aflatoxigenic *A. parasiticus* dose-dependently (Razzaghi-Abyaneh et al. 2008). The leaves were reported to contain thymol **3** ($C_{10}H_{14}O$, 150.21 g/mol) and carvacrol **4** ($C_{10}H_{14}O$, 150.21 g/mol) as effective antifungal components with IC_{50} values of 0.86 and 0.79 μM, respectively.



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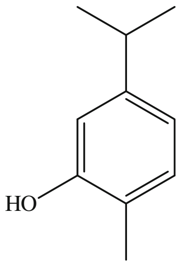

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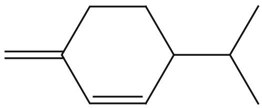
2.2.4 *Thymus vulgaris*

The genus *Thymus* (Lamiaceae) comprises about 350 species of aromatic perennial plants which are native to temperate regions of Europe, North Africa, and Asia. The plant leaves are fragrant and best known for antispasmolytic, antibacterial, antifungal, antiseptic, carminative, anthelmintic, and antitussive properties. In this genus, four species growing in Iran are identified to have growth inhibitory activities against a wide array of fungal pathogens of which *T. vulgaris* (green thyme) is the most important species distributed in all the countries.

Essential oil of leaves of *T. vulgaris* was found to strongly inhibit mycelia growth of an aflatoxigenic *Aspergillus parasiticus* with minimal fungicidal concentration (MFC) value of 1,000 μg/ml (Razzaghi-Abyaneh et al. 2009). Essential oils of *T. x-prolock* and *T. eriocalyx* aerial parts inhibited the growth of *A. parasiticus* dose-dependently (Rasooli and Razzaghi-Abyaneh 2004). The aerial parts were reported to contain β-phellandrene **5** ($C_{10}H_{16}$, 136.23 g/mol) and thymol **3** as the main constituents which are reported to have antifungal properties. Growth inhibition of the yeast pathogen, *C. albicans*, has been reported for the fungus exposed to 10–55 μl/disk of essential oil of *T. daenensis* aerial parts (Ghasemi-Pirbalouti et al. 2009).



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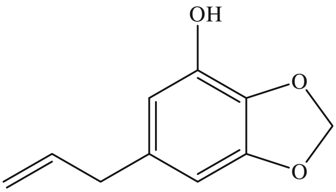
2.2.5 *Heracleum persicum*

The genus *Heracleum* (Golpar in Persian) with 120 species in the world is widely distributed in Asia. Within eight species exist in the flora of Iran, four including *H. persicum*, *H. rechingeri*, *H. pastinacifolium*, and *H. transcaucasicum* are reported to have antifungal properties. *H. persicum* as the most important species is indigenous to the moist valleys of the Elburz Mountains and is related to *H. pubescens* of a wider range. The fruits and leaves of this genus are used as odorant, antimicrobial, antiseptic, carminative, digestive, and analgesic in the Iranian folk medicine.

Essential oil of aerial parts of *H. persicum* was reported to inhibit the growth of *A. niger*, *C. albicans*, and some *Fusarium* species with MIC values of 70–4,500 and 1100 μg/ml for two latter fungi (Firuzi et al. 2010; Naeini et al. 2010). Ethyl acetate extract of plant seed showed strong inhibitory activity against *A. parasiticus* by an IC_{50} value of 370 μg/ml (Alinezhad et al. 2011). In a disk diffusion assay, essential oils of aerial parts of *H. rechingeri*, *H. pastinacifolium*, and *H. transcaucasicum* were reportedly inhibiting the growth of *A. niger* and *C. albicans*

(Firuzi et al. 2010). The main oil constituents of these species and *H. persicum* reported to have antifungal properties were identified by the authors as myristicin **6** ($C_{11}H_{12}O_3$, 192.21 g/mol), elemicin **7** ($C_{12}H_{16}O_3$, 208.25 g/mol), hexyl butanoate **8** ($C_{10}H_{20}O_2$, 172.26 g/mol), and *trans*-anethole **9** ($C_{10}H_{12}O$, 148.20 g/mol), respectively.



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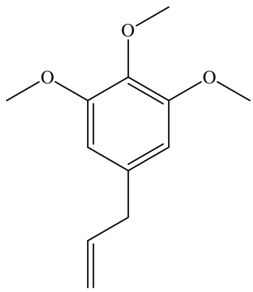

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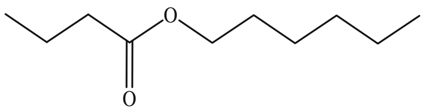

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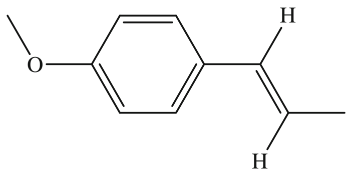

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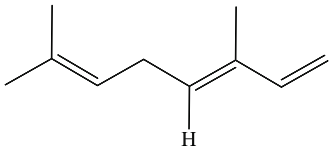
2.2.6 *Artemisia dracunculus*

The genus *Artemisia* (Asteraceae) comprises 200–400 species of which many of them possess different biological activities owing to have a wide range of secondary metabolites like flavonoids, phenylpropanoids, coumarins, terpenoids, and sesquiterpene lactones. *A. dracunculus* L. (Azerbaijan tragon) is one of the most important species native to northwest of Iran which has a long history of use in culinary traditions. It is cultivated 1,340 m above sea level in Urmia, and the leaves are well known for antimicrobial, laxative, carminative, and antispasmodic properties. Usually, an infusion made from a teaspoon of its twigs is consumed an hour before meals.

Essential oil of *A. dracunculus* leaves reportedly showed antifungal activity against aflatoxigenic *A. parasiticus* with a maximum of 70 % fungal growth inhibition at 1,000 μg/ml (Razzaghi-Abyaneh et al. 2009). The main oil constituents, that is, *trans*-ocimene **10** ($C_{10}H_{16}$, 136.23 g/mol), *trans*-anethole **9**, and terpinolene **11** ($C_{10}H_{16}$, 136.23 g/mol), were found to be responsible for plant biological activities. Essential oils of aerial parts of three other native species including *A. scoparia*, *A. sieberi*, and *A. kermanensis* inhibited the growth of pathogenic yeasts, *C. albicans* and *C. glabrata*, by microbroth and disk diffusion methods (Ramezani et al. 2004; Naeini et al. 2009; Khosravi et al. 2011). Camphor **12** ($C_{10}H_{16}O$, 152.23 g/mol) and *β*-thujone **13** ($C_{10}H_{16}O$, 152.23 g/mol), the main oil constituents of *A. sieberi*, are well known to have antifungal properties.



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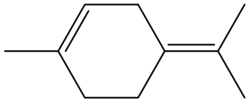

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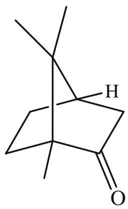

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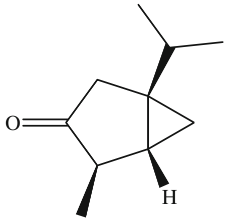

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2.2.7 Zataria multiflora

Zataria multiflora Boiss. (Zattar; Lamiaceae) is a thyme-like plant which grows wild in central and southern parts of Iran. Globally, it is cultivated only in warm climates of Iran, Afghanistan, and Pakistan. The plant is well known as a remedy due to its odorant, food preservative, antispasmodic, antiseptic, analgesic, carminative, anesthetic, antinociceptive and antibacterial and antifungal properties (Zargari 1992). The plant is a rich source of bioactive metabolites suitable for producing medicines. Today, efforts are made to develop it as expectorant, cough suppressant, vaginal douche and pain-relieving creams and antimicrobial and antifungal mouth wash in Iran.

Essential oil of plant aerial parts was shown to effectively inhibit the growth of a wide array of pathogenic yeasts and molds (Gandomi et al 2009; Naeini et al. 2009, 2010, 2011; Saei-Dehkordi et al. 2010; Ghasemi-Pirbalouti et al. 2011). The growth of *C. albicans* and *C. glabrata* was significantly inhibited by the plant oil with MICs of 62–2,000 μg/ml for different fungal strains (Naeini et al. 2009; Saei-Dehkordi et al. 2010). In a disk diffusion assay, the plant oil exhibited strong antifungal activity against main pathogenic *Malassezia* species including

M. furfur, *M. globosa*, and *M. obtusa* in a concentration of 30 μg/disk (Naeini et al. 2011). The growth of various species of pathogenic molds from the genera *Aspergillus* (*A. niger*, *A. flavus*, *A. fumigatus*, and *A. parasiticus*) and *Fusarium* (*F. equiceti*, *F. oxysporum*, *F. poae*, *F. solani*, and *F. verticillioides*) was strongly inhibited by the oil with MICs of 8–256 μg/ml and 66–62 μg/ml, respectively (Gandomi et al. 2009; Naeini et al. 2010; Ghasemi-Pirbalouti et al. 2011).

Thymol **3** and carvacrol **4** identified as main oil constituents of *Z. multiflora* aerial parts may account for the plant antifungal properties.

2.2.8 *Achillea millefolium* subsp. *elborsensis*

A. millefolium (Asteraceae) is a flowering plant grown in any well-drained soil in full sun. Besides the diaphoretic and astringent properties, the plant is well known as a "healing herb" used topically for treatment for wounds, cuts, and abrasions. It has been reported to contain a wide array of bioactive metabolites including asparagine, bitters, coumarins, flavonoids, isovaleric and salicylic acids, and tannins. Among more than 10 subspecies identified, *A. millefolium* subsp. *elborsensis* is native to Alborz Mountains extending about 650 km from west to east along the border of Iran, at the southern shore of the Caspian Sea (Kamrani et al. 2011).

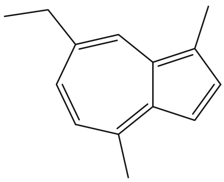
In the only documented work on antifungal activity of this plant variety, a powerful growth inhibitory activity was reported against aflatoxigenic *A. parasiticus* exposed to the flowers' essential oil with an IC_{50} value of 580 μg/ml (Alinezhad et al. 2011). Chamazulene **14** ($C_{14}H_{16}$, 184.27 g/mol) identified as the main constituent of plant oil by the authors may account for antifungal properties due to its proven antimicrobial activities against a wide array of microorganisms.

2.2.9 *Hymenocrater calycinus*

The genus *Hymenocrater* Fisch.et Mey., (Lamiaceae) named Gol-e-Arvaneh in Persian, comprises about eleven species, nine of them reported in Iran of which four species including *H. longiflorus*, *H. calycinus*, *H. yazdianus*, and *H. incanus* are endemic. *H. calycinus* is growing wildly in the northeast of Iran and some parts of Turkmania as a native plant. Another important species, that is, *H. longiflorus*, with strong characteristic aroma is only distributed in Oramanat region, Kermanshah Province, where it is commonly known as "Oraman's tulip" used as a house freshener and an antimosquito agent.

Among four compounds isolated from ethyl acetate and methanolic extracts of *H. calycinus* aerial parts which identified as *β*-sitosterol, ursolic acid, rosmarinic acid, and quercetin 3-O-rutinoside by NMR and MS spectral data, only rosmarinic acid **15** ($C_{18}H_{16}O_8$, 360.31 g/mol) showed antifungal activity against *C. albicans* and *A. niger* in broth dilution assay (Gohari et al. 2009). MIC values of the compound for these fungi were reported as 250 and 1,000 μg/ml, respectively.

Essential oil of aerial parts of *H. longiflorus* exhibited strong inhibitory activity against *C. albicans* and *A. niger* with MICs of 240–480 μg/ml (Ahmadi et al. 2010). Δ-cadinol **16** ($C_{15}H_{26}O$, 222.36 g/mol) and α-pinene **17** ($C_{10}H_{16}$, 136.23 g/mol) were identified as main constituents account for 18.49 and 10.16 % of plant oil, respectively.



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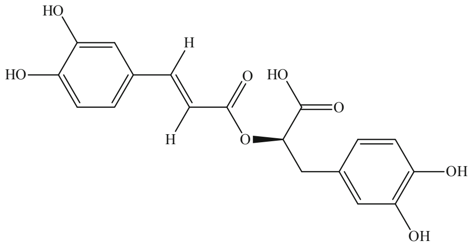

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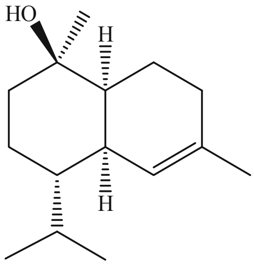

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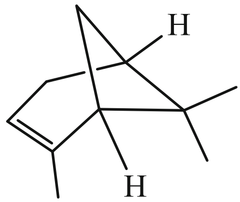

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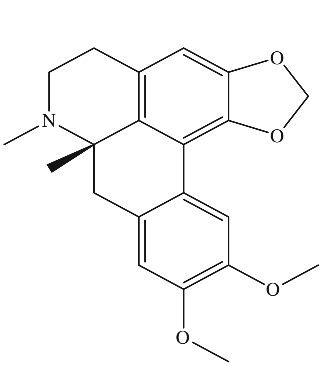
2.2.10 Glaucium oxylobum

The genus *Glaucium* (Papaveraceae) named Lal-e-Koohi in Persian contains about 25 species native to Europe, North Africa, and Southwest and Central Asia of which 19 species are found in Iran as one of the most plant habitats in the world. *Glaucium* species are known in Iranian traditional medicine for their laxative, hypnotic, antidiabetic, and antimicrobial properties.

The methanolic extract and total alkaloids of the aerial parts of *G. oxylobum* showed strong inhibitory activity against *Microsporum gypseum, Microsporum canis, Trichophyton mentagrophytes*, and *Epidermophyton floccosum* as the main causative fungal species of zoonotic dermatophytosis (Morteza-Semnania et al. 2003). Four alkaloids, that is, dicentrine **18** ($C_{20}H_{21}NO_4$, 339.38 g/mol), glaucine **19** ($C_{21}H_{25}NO_4$, 355.42 g/mol), protopine **20** ($C_{20}H_{19}NO_5$, 353.36 g/mol), and α-allocryptopine **21** ($C_{21}H_{23}NO_5$, 369.41 g/mol), were identified by the authors as the bioactive compounds responsible for antifungal activity of this plant. Methanolic extract and isolated plant alkaloids were effective against tested dermatophytes at concentrations of 1,000 and 300 μg/ml, respectively. The fifth alkaloid, *O*-methylflavinantine, did not show any inhibitory effect on tested fungi. Neither isolated alkaloids nor plant methanolic extract was able to inhibit the growth of *C. albicans*, *A. niger*, and *Penicillium* sp.



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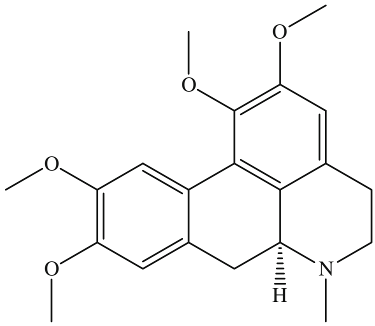

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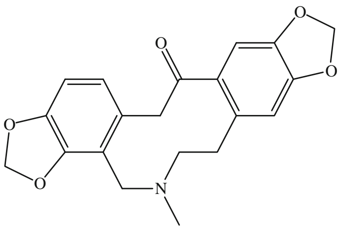

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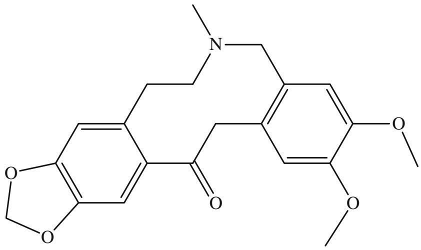

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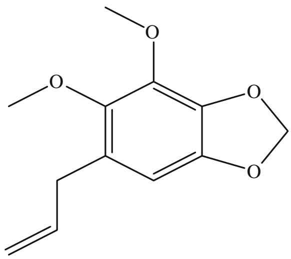
2.2.11 Diplotaenia damavandica

The genus *Diplotaenia* (Apiaceae) was described by Boissier (1844) as a monotypic genus based on *D. cachrydifolia* Boiss. from Iran. *D. damavandica* (kozal in Persian) is a perennial wild herb exclusively found in central Alborz Mountains around Tar Lake, Damavand, Iran. The extracts obtained from the aerial parts of the plant have been reported to have antifungal activity against the genera *Aspergillus*, *Candida*, and *Cryptococcus* with furanocoumarins as the effective constituents (Sardari et al. 2000).

Essential oil of plant leaves reportedly inhibited the growth of *C. albicans*, *Saccharomyces cereviciae*, and *A. niger* with MICs of 3.6–7.2 mg/ml (Eftekhar et al. 2005).The leaves constituents terpinolene **11**, dillapiole **22** ($C_{12}H_{14}O_4$, 222.23 g/mol), γ-terpinene **23** ($C_{10}H_{16}$, 136.23 g/mol), and *p*-cymene **24** ($C_{10}H_{14}$, 134.21 g/mol) were shown to have strong antifungal activities against tested fungi with MICs between 6.6 and 110.1 mM.



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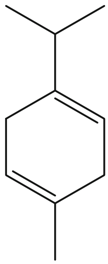

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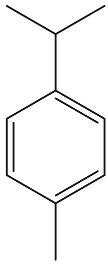

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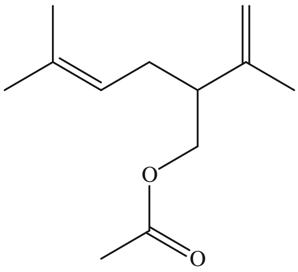
2.2.12 Semenovia tragioides

The genus *Semenovia* (Apiaceae) consists of about 300 genera and 3,000 species of aromatic permanent plants growing mostly in the mountain regions of Iran and Turkey, and Mediterranean region (Ghahreman 1995). The plant is mainly used as edible vegetable and as sources of volatile oils and drugs. Among 20 *Semenovia* species growing in Asia, eleven are found in Iran and five are endemic. *Semenovia tragioides* is one of the most important endemic species of Iran that its fragrant leaves and fruits are frequently used as carminative and flavoring agent in southwest Iran.

Essential oils of aerial parts of *S. tragioides* exhibited strong antifungal activity against pathogenic yeast *C. albicans* with MIC of 5 mg/ml, while the plant oil did not show any obvious effect on the growth of mycelia fungus *A. niger* (Bamoniri et al. 2010). The main compounds identified by the authors in plant oil including lavandulyl acetate **25** ($C_{12}H_{20}O_2$, 196.28 g/mol), geranyl acetate **26** ($C_{12}H_{20}O_2$, 196.28 g/mol), *trans*-ocimene **10**, *p*-cymene **24**, and γ-terpinene **23** may account for its antifungal properties.



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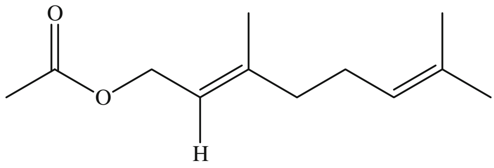

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2.3 Concluding Remarks and Future Perspectives

Dramatic increase in emerging fungal diseases, restricted availability of antifungal drugs suitable for treating systemic fungal infections, and appearance of multi-drug-resistant fungi as major global health problem in the twenty-first century urge the health organizations and pharmaceutical industries to return back to biodiversity for more effective, safer, and broad spectrum antifungals that battle against these life-threatening microbial infections. Among existing biodiversity, medicinal plants are still in the first line of investigation owing to have a large number of bioactive metabolites with huge structural diversities. In this chapter, we carried out a comprehensive literature review with the aim to introduce antifungal activities of medicinal plants from flora of Iran. We characterized 83 native medicinal plants with proven benefits against a wide array of fungal pathogens. Actually, majority of enlisted plants were shown to contain different numbers of bioactive constituents with strong antifungal activities when isolated from same or other plants in bioassays. The α-bisabolol from *M. chamomilla* is a very good example of such compounds which has a potential for being a unique antifungal drug candidate. We believe these comprehensive data could help the researchers in further phytochemical characterization of medicinal plants, which finally will lead to development of more effective drugs and candidates suitable for treatment for life-threatening fungal infections. Development of bioinformatic and computational chemistry approaches to routine screening for antifungal drug discovery from medicinal plants will accelerate such process in a best way.

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