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Review of Essential Oils as Antifungal Agents for Plant Fungal Diseases

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Abstract: Fungi cause huge yield losses due to their ability to cause serious devastating diseases to the crops. Minimizing their effect on the crops need to get a promising way of controlling them. Therefore, the use of essential oils could be a good option to tackle the challenge of fungal diseases. Essential oils are natural products that are extracted from plants by different methods. They have been used for a long history of time for different purposes. Nowadays there is a huge interest to use them as plant protection product to be alternative for chemicals like fungicides. The main reasons for choosing them are their antimicrobial activity and their environmental friendly. As we observed from the antifungal trials in different literature, the essential oils have a great antifungal effect on many plant pathogens and inhibited most of the tested plant pathogens in the laboratory. Thus, essential oils could be a control agent for plant fungal diseases and further investigation is required to use in the field.

Keywords: Antifungal, Essential oils ,Fungal diseases,

Bitki fungal hastalıkları için antifungal ajan olarak uçucu yağlar

Özet: Funguslar, mahsullerde ciddi tahrip edici hastalıklara neden olma yeteneklerinden dolayı büyük verim kayıplarına neden olmaktadır. Mahsuller üzerindeki etkilerini en aza indirgeme ve onları kontrol etmenin bir yolunu bulmak gerekir. Bu amaçla, uçucu yağların kullanılması, fungal hastalıklarının zorluğuyla mücadele etmek için iyi bir alternatif seçenek olabilir. Esansiyel yağlar, bitkilerden farklı yöntemlerle elde edilen doğal ürünlerdir. Farklı amaçlarda uzun süre kullanılan maddelerdir. Günümüzde fungisitler gibi kimyasallara alternatif olabildikleri için onları bitki koruma ürünü olarak kullanmaya büyük ilgi duyulmaktadır. Bunları seçmenin ana nedenleri, antimikrobiyal aktiviteleri ve çevre dostu olmalarıdır. Farklı literatürdeki antifungal çalışmalardan gözlemlediğimizde, uçucu yağlar birçok bitki patojeni üzerinde büyük antifungal etkiye sahiptir ve test edilen bitki patojenlerinin çoğunu laboratuarda inhibe ederler. Bu nedenle, uçucu yağlar, bitki fungal hastalıkları için bir kontrol maddesi olabilir ve tarlada kullanılabilmeleri için daha fazla araştırma yapılması gerekir.

Anahtar kelimeler: Antifungal, Funal hastaliklar, Uçucu yağlar

Introduction

Because of the speedy growth of the world population, there is a growing demand for food, so it is necessary to tackle the challenges of food production including plants diseases. The plant disorders caused by fungi are the most devastating diseases in the agricultural farms, which causes huge losses to the yields of crops. In addition to that, there are many other important diseases caused by bacteria, nematodes, virus, and phytoplasma to the plant. Management of plant diseases to reduce their effect are in urgent needs. Crop rotation, use of disease-free seeds, resistant varieties are among the control practices of plant diseases. Although chemical control measures are other important means to prevent plant diseases, their negative impact on the environment when it is used inappropriately made them unwelcomed all the time. When higher doses of chemicals are applied to the resistant varieties, it increases the level of toxic residues in the product (Daferera *et al*.2003). Other disadvantages of intensive use of chemicals are the development of resistant strains of the target pathogen (Pasche *et al*.2004). Nowadays it is known that there are various natural products from plants like essential oils those have the ability to suppress the growth of plant pathogens and reduce disease development, while they are safe to the environment and convenient as integrated pest management (Bowers and Locke, 2004). It can be said that EOs are non-phytotoxic in nature and safe for consumers. For seeking of economic and environmental sustainability, the use of products like essential oils over other chemicals has its own great value.

Essential oils are plant-based products that have potential use of different important matters of life. They are extracted from parts of the plant like leaves, flowers, roots, stems etc. In centuries, the people used them as a flavoring agent, aromatic requirements and medicinal purposes. Nearly 3000 EOs are known currently in which 300 of them are used in the flavoring and fragrance market (Burt, 2004). EOs contain multiple compounds that make their chemical, physical and biological properties (Regnault-Roger, *et al*., 2012). It is believed that the EOs with good antifungal activity have phenolic or aromatic components in their chemical composition (Burt, 2004). Plants secrete these secondary metabolites to defend themselves against pest organisms (Amri, 2017). Thus, their antimicrobial and insecticidal activities are un-negligible. Previous researches mentioned that EOs could be a solution for plant pathogenic fungi and food associated fungi (Sitara *et al.*, 2011; Parveen et al., 2010).

Essential oils extraction methods from plants

There are several techniques used for essential oil handling from plant raw materials (Wang and Weller, 2006)**.** Hydro-distillation, steam distillation, solvent extraction, cold pressing, and microwave-assisted hydro-distillation are the most commonly used methods of EOs isolation. Most of in vitro applications in the antifungal trials of essential oils that are going to be displayed here indicate that hydro-distillation method using Clevenger apparatus is a very common method of essential oil handling**.**

Main components of the essential oils

The constituents of the essential oil is what gives the special odor and smell of that particular oil. These compounds are also responsible for the antimicrobial characteristics of the EOs. The composition of the EOs depends on the extracted plant species, geographical location of the plant, extraction time and the used technique for handling it (Tongnuanchan and Benjakul, 2014). Constituents of the EOs can be categorized under terpene hydrocarbons and oxygenated compounds. Terpenes are the largest components represented in the essential oils and they do classified as monoterpenes, sesquiterpenes, di-terpenes, triterpenes and poly-terpenes. Esters, aldehydes, ketones, alcohols, phenols, and oxides are the oxygenated compounds present in EOs and they are odoriferous compounds.

Essential oil's mechanism of action

Factors that affect the activity of essential oils are their composition, functional groups present in their active components, and their synergistic interactions (Dorman and Deans, 2000). The antimicrobial mechanisms of action by the EOs vary in the type of the EOs and the strain of the microorganism used (Chouhan *et al*., 2017). Although the mechanisms that made essential oils effective as an antimicrobial agent are not fully known, there are several proposed possible mechanisms. Researches revealed that accumulation of the essential oils in the cell, effect of cell permeability, disruption of major organelle membranes, alteration of the general morphology, (Hua, *et al*., 2017, Bajpai *et al*., 2013, *Tian et al*., 2012,), which causes leakage and death of the cell of the organism are the mechanism of action by the EOs. Concerning the antifungal activity particularly, their mechanism of action seems to involve penetration through cell walls and direct damage to both cytoplasmic and mitochondrial membranes (Bakkali *et al*., 2008).This causes changes in permeability which leads to leakage and finally results in the death of the cell (Bakkali *et al.*, 2008). Iscan et al. (2016), reported extensive fungal cell wall and damage of cytoplasmic membrane after application of thymoquinone; a major component of the essential oil of black cumin seed. EOs could affect spore germination, germ tube elongation and inhibit the growth of fungal mycelia (Sivakumar, and Bautista-Baños, 2014). Formation of vacuole fusion in the cytoplasm, creation of numerous folding lomasomes, detachment of the plasma membrane from the cell wall and malformation of the fibrillary layers of the cell wall are the common alterations observed on the mycelia or fungal spores (da Cruzet al., 2013).

Antifungal activities of essential oils

Many researchers have reported antifungal potential of various plant extracts and plant essential oils. EOs can be one of the most reliable natural products for fungal inhibition (Kalemba and Kunicka, 2003). Among the plant species, that have been investigated many of their essential oils inhibit post-harvest fungal infections and prolong the shelf life of many crops in the storage conditions (Tripathi and Dubey, 2004). Mohammadi et al. (2012) studied the use of essential oils to control postharvest fruit decay and in their research they got that essential oils decreased weight loss of the fruit, increased their life storage and positively affected the quality of the fruits. Most of the researches on the effects of essential oil on plant pathogens are in vitro experiments and there are plenty of studies those together witnessed the antimicrobial characteristic of essential oils. Bashir and Tahira (2012), reported essential oils from *Eucalyptus camaldulensis* to have antifungal activity against *Fusarium solani.* Tatjana Stević et al. (2014) when they studied antifungal activity of essential oils against twenty-one fungi, as result they concluded the inhibition properties of the essential oils and proved that Savory, Oregano, Thyme, and Rose oils were the best inhibitors of the fungi.

Mysore *et al*. (2014) reported complete growth inhibition caused by EOs when they tested the antifungal activity of cinnamaldehyde, eugenol, peppermint and clove EOs and their combinations against species of *Aspergillus*, *Fusarium*, *Penicillium* and *Rhiz opus* in *in vitro* and tomato fruit system (*in-vivo*) at or below 0.6% level *(in vitro*) and 80 µL (in Tomato fruit) of EOs except peppermint oil. In a research done by Kordali et al.,(2016), they found essential oils from fruits of four genotypes of *Myrtus communis* became very effective against nineteen plant pathogenic fungi and their antifungal effect was higher then benomyl; well-known commercial fungicide.

Most of the laboratory experiments show the ability of essential oils to stop the growth of the pathogenic fungi, where some of them reveal fungicidal and some other fungi-static effect. The ability of the essential oil to act as fungicide or fungi-stat is dependent on its active compounds.

As the intentions towards the use of essential oils as plant protection products increased the researches in this subject increased. Some of the studies that relate antifungal activities of the essential oils with their references are listed in the table below.

Table: Researches on antifungal activity of essential oils

Essential oils or plant species extracted from them	**Inhibited fungi**	**Study mode**	**References**
Carnation, Caraway, Thyme oils	*Altenaria solani*	*In vitro* and *In vivo*	El-Mougy, 2009
Eucalyptus staigeriana,	*Alternaria solani*	*In vitro* and *In vivo*	Tomazoni *et al.*, 2017

Eucalyptus globulus Cinnamomum camphora			
Origanum vulgare L. ssp. hirtum) Thymus vulgaris L. Citrus limon L.	*Botrytis cinerea Penicillium italicum P. digitatum*	*In vitro* and *In vivo*	Vitoratos *et al.*, 2013
Cestrum nocturnum L.	*Colletotrichum capsici, Fusarium oxysporum, Fusarium solani, Phytophthora capsici, Rhizoctonia solani Sclerotiniasclerotiorum*	*In vitro* and *In vivo*	Al-Reza *et al.*, 2009
Thymus leptobotrys	*Penicillium digitatum, Penicillium italicum Geotrichumcandidum.*	*In vitro*	Ameziane *et al.*, 2007
Lippia alba (Mill.) N.E. Brown	*Alternaria solani* Sorauer	*In vitro*	Tomazini, *et al.*, 2016
Origanum onites L., *Thymbra spicata* L., *Lavandula stoechas* L. *subsp. stoechas* L., *Foeniculum vulgare* Mill. *Laurus nobilis* L.	Alternaria alternata	*In vitro*	Soylu *et al.*, 2015
Commiphora molmol	*Aspergillus flavus, Cladosporium sp., Alternaria alternata, Fusarium oxysporum F. solani*	*In vitro*	Perveen *et al.*, 2018
Eucalyptus camaldulensis Dehnh.	*Fusarium solani F. oxysporum F. verticillioides F. proliferatum F. subglutinans*	*In vitro*	Gakuubi *et al.*, 2017
Cironella oil Camphor oil	*Aspergillus niger, Aspergillus flavus Penicillium sp.*	*In vitro*	Mahilrajan *et al.*, 2014
Pimpinella anisum, Chamomilla recutita L., *Thymus vulgaris, Origanum vulgare* L.	*Penicillium citrinum, Penicillium crustosum, Penicillium expansum Penicillium griseofulvum Penicillium brevicompactum*	*In vitro*	Felšöciová *et al.*, 2015
Aquilaria sinensis (Lour.) Gilg	*Lasiodiplodia theobromae Fusarium oxysporum, Candida albicans*	*In vitro*	Zheng *et al.*,2013
Mentha spicata	*Ascochyta rabiei*	*In vitro*	Bayar *et al.*, 2018
Vitex agnus-castus L. *Myrtus communis* L.	*Fusarium oxysporum* f. sp. *radicis-lycopersici* (Sacc.) *Rhizoctonia solani* J.G. Kuhn., *Sclerotinia sclerotiorum* (Lib.) de Bary *Verticillium dahliae* Kleb.	*In vitro*	Yılar *et al.*, 2016

Origanum acutidens and its components carvacrol, thymol p-cymene	*Alternaria alternate* *Alternaria solani* *Botrytis sp.* *Fusarium acuminatum* *Fusarium culmorum* *Fusarium equiseti* *Fusarium nivale* *Fusarium oxysporum* *Fusarium sambucinum* *Fusarium semitectum* *Fusarium solani* *Monilinia sp.* *Pythium ultimum* *Phytophthora capsici* *Rhizoctonia solani* *Sclerotinia minor* *Verticillium dahliae*	*In vitro*	Kordali *et al*.,2008
Nepeta meyeri	*Alternaria solani* *Fusarium verticilloides* *Fusarium semitectum* *Fusarium culmorum* *Fusarium proliferatum* *Fusarium graminearum* *Fusarium chlamydosporium* *Fusarium sambucinum* *Fusarium scirpi* *Fusarium equiseti* *Nigrospora oryzae* *Phytophthora capsici* *Phoma sp.* *Sclerotinia sclerotiorum* *Sclerotonia sp.* *Sclerotium rolfsii*	*In vitro*	Kordali *et al*., 2013

Conclusion

Essential oils are plant-based products that have a long history of use. They have promising action of antimicrobial and insecticidal effect. That is why EOs are used to test their activity by many researchers to see their potentiality for controlling fungal plant diseases. All the mentioned experiments in this review showed the high capability of the essential oils to act as antifungal agents. Their environmental friendly characteristics make them interested by the researchers those exploring products that have desirable effects on the target organisms with no or less negative impact on the environment. According to Bakkali, *et al.* (2008), essential oil's high volatility, their odor, and price, as well as their effect on fruit flavor, are common problems in their application. Currently, EOs are used mostly for food preservation and reduction of post-harvest losses but it’s believed in the near future they will be used in a broad category in many fields as bio-products to avoid the problems encountered by the use of chemicals.

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