Studies in Fungi

REVIEW

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https://doi.org/10.48130/sif-0024-0012
Studies in Fungi **2024**, 9: e012

Alternaria alternata: the most common pathogen on date palm

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Abstract

Alternaria alternata is one of the most widespread fungus that infects a wide range of plants worldwide due to its ability to infect diverse host plants, this fungus presents on date palms and their environment. This review discusses information about the species of *Alternaria* that infect date palms and focuses on the fungus *A. alternata* and its control strategies. It also discusses the importance of the genus *Alternaria* and the environmental factors that help in its spread, such as temperature and humidity. It also mentions the diseases caused by the fungus *A. alternata*, such as inflorescence rot, leaf spot, shoot hole leaf, and fruit rot on date palms, and the common symptoms resulting from the infection. In addition, the review refers to control methods in general, such as chemical control, cultural practices, and resistant varieties, as strategies used to limit the spread of the fungus *A. alternata* and thus prevent the occurrence of diseases.

Citation: Alasadi RMS. 2024. *Alternaria alternata*: the most common pathogen on date palm. *Studies in Fungi* 9: e012 https://doi.org/10.48130/sif-0024-0012

Introduction

The cultivation and growth of date palms are accompanied by the growth of several fungi on its various parts. Some of these fungi are beneficial and exist naturally on healthy parts without causing any harm to the plant, or can be applied to promote the growth of the plant. The relationship between fungi and plants may be symbiotic, especially with root fungi, which play a very important role in promoting plant growth by contributing to making some nutrients in the soil ready for absorption[1]. In addition to protecting the plant against pathogens, such as stimulating plant resistance and others. An example of beneficial fungi are mycorrhizal fungi, as adding them to the soil contributes to protecting palm seedlings against the fungus *Fusarium chlamydosporum*, which causes palm seedling decline disease, by reducing the infection with this pathogen[2]. Also, Trichoderma fungus plays an important role in combating some date palm pathogens. However, some other fungi cause diseases by infecting one of the parts of the palm tree. These fungi may be specialized in infecting one part of the palm, as they do not infect another part or are not even present on it, such as the fungus *Mauginiella scaettae*, which causes inflorescence rot disease, as this fungus attacks only the inflorescence of palm[3]. Likewise, the fungus *Serenomyces phoenicis* that causes rachis blight disease, which does not infect other parts of the leaf except the leaf rachis[4]. These fungi were not isolated from palm parts other than the parts present on them. There are several fungi that can grow on all parts of the palm tree as a pathogen or as a fungus accompanying the infection. Also, it can be found on the outer surface of insects and their larvae that infect the date palm. One of the most abundant and important of these fungi is *Alternaria alternata*. This fungus causes significant diseases in date palm, impacting yield and quality, and is also present in some infection sites as a secondary pathogen compounding the damage caused by primary infections. For this reason, this article highlights the exploration of the properties of this fungus, the diseases it causes, and control strategies, ultimately ensuring healthier date palm trees and improved yields.

Alternaria fungus

Alternaria is found in various regions of the world as a saprophytic fungi in the soil or on plant residues[5–7]. However, some of its species infect a number of plants and cause diseases[8]. It is one of the important fungi that causes diseases in the field, such as heart rot disease in pomegranates[9], leaf blotch and fruit spot disease on apples[10], or post-harvest disease, for example, broccoli black spot[11], tomato fruit rot[12], apple fruit rot[13], and kiwi fruit rot[14]. This fungus is one of the important fungi that cause leaf spot diseases on plants, such as gerbera leaf spot disease[15], blackberry leaf spot disease[16], and soybean leaf spot disease[17]. Alternaria were described by Nees von Esenbeck[18], with *A. tenuis* being the species representing the general description[19]. There are approximately 368 species belonging to the genus Alternaria[7]. The sexual form of Alternaria features small, dark brown, round to oval structures that are either embedded or on the surface. These structures have single chambers with small openings and thin walls. Inside, there are cylindrical sacs containing spores, surrounded by broad cellular filaments and ellipsoidal to fusiform, pigmented spores, the sexual form has been documented in species within the sections Alternaria, Crivellia, Embellisioides, Eureka, Infectoriae, Nimbya, and Panax.[7,20]. Species of this genus produce asexual conidia that are divided longitudinally and transversely, are dark in color, and are in the form of branched or single chains[21]. The fungal species can grow in different environmental conditions. When the environmental conditions are not suitable for growth, they remain in the soil, on the dead plants, or in the host plant tissues in the form of

spores or mycelium[22]. Fungus spores germinate when appropriate moisture is available, and the appropriate temperature for germination ranges between 25–35 °C[23]. The fungus is transmitted from one place to another in the form of spores by the wind. Among the characteristics that distinguish these types of fungi are the production of melanin pigments in the spores and the production of toxins for pathogenic species[22]. In addition, it is characterized by its ability to change its lifestyle from a saprophytic fungus to a pathogenic fungus[22].

Alternaria species on date palms

There are a number of Alternaria fungal species that have been isolated from different parts of the date palm. Most of these species have been isolated as causes of leaf spot diseases (Table 1). Also, some of them accompanied insects and mites that attack palm trees[24]. These species are namely: *A. alternate*[25,26], *A. longipes*[26], *A. diynthicola*[27] *A. radicina*[28], *A. chlamydospra*, *A. arborescens*, *A. consortialis*[29]. *A. raphani*[30], *A. tomato*, and *A. burnsii*[31]. The fungus *A. alternata* is one of the most abundant species in the date palm surroundings.

Table 1. Presence of Alternaria species in date palm orchards across various regions.

No.	Alternaria species	Date palm portions				
		Inflo	Fruits	Leaves	Roots	Insects & mites
1	*Alternaria alternata*	+	+	+	+	+
2	*A. arborescens*	–	–	+	–	–
3	*A. burnsii*	–	–	+	–	–
4	*A. chlamydospra*	–	–	+	–	–
5	*A. consortialis*	–	–	+	–	–
6	*A. dianthicola*	–	–	+	–	+
7	*A. longipes*	–	–	+	–	–
8	*A. plurispora*	–	–	+	–	–
9	*A. radicina*	–	–	+	–	–
10	*A. raphanin*	–	–	+	–	–
11	*A. tenuissima*	–	–	+	–	–
12	*A. tomato*	–	–	+	–	–

+, present; –, not present.

Table 2. Scientific classification of *A. alternata*.

Biological classification	Name
Kingdom	Fungi
Subkingdom	Eumycota
Phylum	Imperfect fungi
Class	Hypomycetes
Order	Moniliales
Family	Dematiaceae
Genus	*Alternaria*
Species	*Alternata*

Fungus *Alternaria alternata*

Fungi belong to the kingdom fungi and the phylum Deuteromycota, also known as the imperfect fungi[22] (Table 2). The fungus secretes a group of enzymes that help it cause plant diseases. In addition they produce two types of toxins, which are non-host-specific toxins such as Tentoxin[32] and host-specific toxins (Table 3). These toxins are produced by pathogenic isolates of the fungus *A. alternata*, while non-pathogenic isolates do not produce them. These toxins have a role in increasing the severity of the disease and also are considered toxic to other plant species generally[33]. Fungi can grow on several artificial culture media, such as: Cornmeal agar, potato dextrose agar, V8 agar, glucose-nitrate agar, and yeast peptone agar. The growth of fungal colonies and the size of the spores formed are affected by the components of each medium. It was noted that the size of the spores formed on culture media was smaller than the size of the spores formed when fungal isolates were grown on tomato stem pieces in the laboratory[34]. The fungus *A. alternata* that grow on potato dextrose agar medium at 25 °C, forms a colony with a dark gray to olive color and conidia in chains. The shape of the conidium is oval or elliptical, divided transversely and longitudinally, with a short beak (Fig. 1). This fungus is found on date palm trees, either as a secondary cause of disease, such as false frond disease (yellowing of fronds)[35], offshoot decline disease[36] or it exists as a primary pathogen.

Diseases of *A. alternata* on date palms

Inflorescences rot disease

This is one of the important diseases on date palms in several countries, such as Iraq, the Arabian Gulf countries, and North Africa. It is also found in Iran, Spain, and Italy. The main cause of this disease is *Mauginiella scaettae* Cav. This fungus infects inflorescences and causes them to rot completely or partially. In addition, several fungi associated with inflorescences rot were isolated, such as *Fusarium moniliforme*, *F. solani*, *F. oxysporum*, *F. proliferatum*, and *Thielaviopsis paradoxa*. Also, this disease is caused by the bacterium *Serratia marcescens*[45,46]. Furthermore, it has been noted that this disease is caused by the fungus *A. alternata*. This fungus infects the inflorescences and causes rusting of the flower[47,48] (Fig. 2a). This fungus was isolated individually from palm pollen samples that showed symptoms of inflorescence rot. This fungus infects several palm varieties: Ghanami, Halawi, Sayer, Khadrawi, and Dairi. The pathogenicity

Table 3. Host-specific toxins produced by *A. alternata*.

Fungi species	Host plant	Disease	Toxin	Ref.
Alternaria alternata	Spotted knapweed	Black leaf blight of spotted knapweed	Maculosin- toxin	Stierle et al.[37]
Alternaria alternata	Sunflower	Leaf disease of sunflower	AS-toxin	Liakopoulou-Kyriakides et al.[38]
Alternaria alternata f.sp. *citri*	Rough lemon	Leaf spots of rough lemon	ACR-toxin	Masunaka et al.[39]
Alternaria alternata f.sp. *fragariae*	Strawberry	Black spot of strawberry	AF-toxin	Maekawa et al.[40]
Alternaria alternata f.sp. *kikuchiana*	Japanese pear	Black spot of Japanese pear	AK-toxin	Tanaka et al.[41]
Alternaria alternata f.sp. *lycopersici*	Tomato	Stem canker of tomato	AAL-toxin	Bottini & Gilchrist[42]
Alternaria alternata f.sp. *mali*	Apple	Alternaria blotch of apple	AM-toxin	Johnson et al.[43]
Alternaria alternata f.sp. *tangerine*	Tangerine	Alternaria brown spot	ACT-toxin	Kohmoto et al.[44]

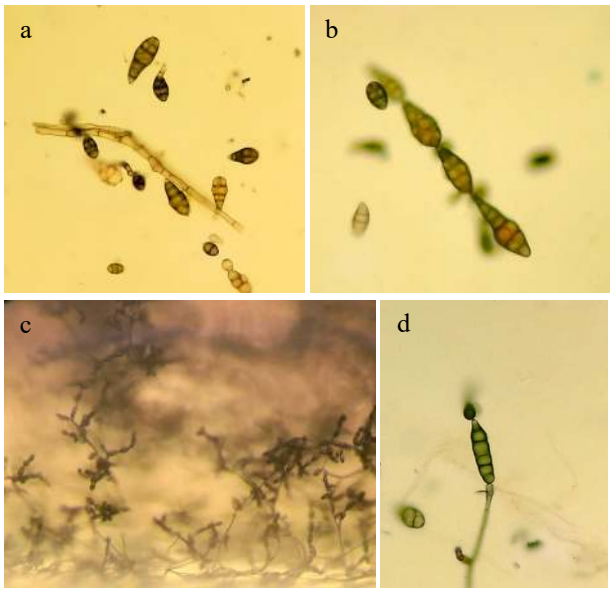

Fig. 1 Morphology of *A. alternata* on (PDA). (a) Different shape and size of conidia. (b) Conidia in a chain with four conidia. (c) Conidia pattern on (PDA) surface. (d) Conidiophore development.

test demonstrated the ability of the fungus *A. alternata* to infect healthy pollen and cause symptoms similar to natural infections in the field[47].

Fruit rot

Date palm fruits are exposed to infection bu several fungi during their growth stages, which leads to their damage. Thus, it affects its economic value. Factors that contribute to infection are humidity, rain, cracks and wounds on the fruits. This disease is caused by several fungi that attack the fruits, and yield losses may reach about 70% generally. The infection appears either as rot near the apical end of the fruits[49] or as lateral rot, as in cases of infection with the fungus *A. alternate*[49,50] (Fig. 2b). The symptoms on infected fruits are in the form of dark black spots, which is a soft rot that expands as the infection progresses. Thus, it leads to shrinkage and fall of fruits. Laboratory experiments have proven that the fungus can cause infection at all stages of the fruit except the Tamar stage, Table 4, and the results showed that the fungus was not able to infect unwounded fruits[50].

Leaf spot disease

Date palm leaves are infected with several fungi that cause tissue damage and death. The affected areas appear as spots of different sizes and shapes, which may be circular, longitudinal, regular, or irregular. Although this disease spreads throughout palm cultivation, it is not an epidemic disease. The disease severity depends on the type of date palms variety, agricultural practices, and environmental conditions. Usually, the infection begins on the old leaves and then spreads to the inner fronds of the palm tree. The fungus *A. alternata* is one of the main and common causes of leaf spot diseases. Symptoms of spotting due to infection with the fungus *A. alternata* appear on both sides of the leaflets and sometimes on the rach of the leaf. (Fig. 2c). It appears as light brown spots with dark brown to reddish edges[47]. Also, the fungus *A. alternata* may be involved with other fungi in causing leaf spot, as the fungus *A. alternata* and *Fusarium sp*. were isolated from the same spots on the leaf[27]. The *A. alternata* frequency when isolated from leaf spot was 68% compared to the frequency of fungi associated with causing the same spot[51].

Shoot-hole disease

The fungus *A. alternata* causes small shoot-holes on date palm leaves. The infection begins in the form of brown or pale spots surrounded by a yellow halo or brown rings, and as the infection progresses, it leads to the separation of the affected tissue from the healthy tissue and thus its fall (Fig. 2d). These symptoms appear on both sides of the leaflets in different places[47,52]. The effectiveness of this fungus has been proven in the laboratory to cause infection and the appearance of hole symptoms on the leaves. Date palm varieties differ in their sensitivity to infection with this fungus[52].

Diagnostic process

There are several methods that can be followed to diagnose infection with the fungus *Alternaria alternata*. First, a visual diagnostic, although this method is inaccurate in determining the type of pathogen. However, it may be useful as a preliminary diagnosis of infection. For example, it is not possible to determine the type of pathogen of inflorescence rot through field observations because this disease is caused by several pathogens. Therefore, all of these pathogens infect inflorescence and cause symptoms of rot. The second method is microscopic examination of infected tissues and isolation of the pathogen: examining infected tissues under a microscope allows fungal structures such as spores and mycelium to be seen. By culturing pieces of these tissues on culture media, pure isolates can be obtained. Thus facilitating the diagnosis and identification of the fungus *A. alternata*. However, the morphological similarity between the Alternaria fungus genera may lead to incorrect diagnosis, and therefore the molecular diagnosis method can be used, which is considered one of the more modern and accurate methods of diagnosis. Also,

Fig. 2 Date palm diseases caused by *A. alternata*. (a) Inflorescence rot. (b) Fruit rot. (c) Leaf spot. (d) Shoot-hole.

Table 4. Infection percentage of different varieties of dates and their growth stages with the fungus *A. alternate*[50].

Fruit stage growth of the date palm													Cultivar
Tamar			Rutab			Khalal			Kimri				
Control	Unwounded	Wounded	Control	Unwounded	Wounded	Control	Unwounded	Wounded	Control	Unwounded	Wounded		
0	0	0	0	0	30%	0	0	63%	0	0	51%		Sayer
0	0	0	0	0	33%	0	0	50%	0	0	55%		Barhi
0	0	0	0	0	20%	0	0	22%	0	0	32%		Zahidi
0	0	0	0	0	11%	0	0	44%	0	0	21%		Hallawi

through epidemiological studies, it is possible to determine the date of infection, especially seasonal diseases such as inflorescence rot disease and fruit rot disease in general. However, all of these methods should be applied to obtain accurate and reliable results in determining infection with the fungus *A. alternata*.

Management strategies

Cultural practices

Taking care of horticultural services is considered a basic step in combating diseases, as this is done by removing parts of palm trees infected with the fungus *A. alternata* and burning them. Sterilizing the tools used in pruning while avoiding causing wounds that may cause diseases. Plant palm trees at appropriate distances and organize the irrigation process, which will reduce humidity and thus limit the spread of fungi between trees. Also remove weeds, which may be a secondary source of infection.

Chemical control

It is considered a fast and effective method of control, but it causes environmental damage if not applied correctly. Therefore, specific fungicides must be used to target the pathogen *A. alternata* and thus prevent its spread. A study found that foliar application of two fungicides significantly reduced the incidence of *Alternaria* sp. infection on date palms, with a reduction of 17.87% for pentanol and 22.56% for Score. Additionally, these fungicides significantly inhibited the growth of the pathogen *in vitro*[53]. Another study was conducted by Kassem et al.[54] to test the effect of fungicides Bellis, Maystic, Rovral, and Switch on the development of date fruit rots caused by several pathogens, including *A. alternata*. The results showed that Bellis, at all tested concentrations was an effective fungicide in controlling fruit decay caused by *A. alternata*, Bellis recorded disease severity of 28.20%, 17.79%, and 8.85% , at concentrations 125, 250, and 500 ppm respectively, compared to other fungicides and the control treatment.

Resistant varieties

Selecting and planting resistant varieties of date palm is an important way to remove diseases caused by the fungus *A. alternata*. Thus, it will reduce the costs of using fungicides and their harm to the environment. Natural resistance can be identified in certain date palm varieties to *A. alternata* infection, then can be selectively grown. Additionally, understanding the genes responsible for resistance and their mechanisms is crucial. Genetic engineering techniques can be used to introduce resistant genes, allowing for genetic modification in date palms.

Biological control

Biological control has been used to control *A. alternata* by applying microorganisms like fungi and bacteria. In a study conducted by Alasadi & AlSadoon[48], the antagonism between *Trichoderma harzianum* and *A. alternata*, which causes inflorescence rot diseases, was shown to have an antagonism degree of 73.3%. Mansour et al.[55] found that *A. alternata* isolated from leaf spots on date palm was inhibited by *T. harzianum* (70.56 %) and *Bacillus* spp. (42.2%) *in vitro*.

Conclusions

The *A. alternata* fungus is considered very important because it causes many diseases in date palms and thus affects their productivity. To protect date palms, it is necessary to understand the biology of this fungus and the environmental conditions suitable for its spread. In addition, pointing out the various control methods that limit the spread of this fungus in date palm orchards. Thus, future research should focus on molecular technology to develop resistant date palm varieties to *A. alternata*, besides developing predictive models that help to forecast pathogen outbreaks.

Author contributions

The author confirms the sole responsibility for all aspects of the research and manuscript preparation.

Data availability

All data for this study were gathered from the sources listed in the reference section and analyzed accordingly.

Conflict of interest

The author declares that there is no conflict of interest.

Dates

Received 1 May 2024; Revised 15 July 2024; Accepted 25 July 2024; Published online 3 September 2024

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